HYDROGEOLOGIC SETTING, WATER LEVELS, AND QUALITY OF WATER FROM SUPPLY WELLS AT THE U.S. MARINE CORPS AIR STATION, CHERRY POINT, NORTH CAROLINA

By Orville B. Lloyd, Jr., and Charles C. Daniel, III

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Multiply inch-pound unit	By	To obtain metric unit
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi)	2.590	square kilometer (km)
	Volume	
gallon (gal)	3.785	liter (L)
	0.003785	cubic meter (m)
million gallon (Mgal)	3,785	cubic meter (m)
	Flow	
million gallon per day (Mgal/d)	0.04381	cubic meter per second (m /s)
gallon per minute (gal/min)	3,785	liter per minute (L/min)
gallon per day (gal/d)	0.0038	cubic meter per day (m /d)
	Transmissivity	
foot squared per day (ft /d)	0.0929	square meter per day (m /d)
	Temperature	
degree Fahrenheit (^{O}F)	5/9 (^{O}F-32)	degree Celsius (^{O}C)
	Mass	
ounce (oz)	28.35	gram (g)
ounce (oz)	0.02835	milligram (mg)
ounce (oz)	0.00002835	microgram (ug)
	Specific conductance	
micromho (umho) per centimeter at 25 degree Celsius	1	microsiemens (uS) per centimeter

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level of 1929."

CONTENTS

Page

Abstract 1
Introduction 2
    Location and background 2
    Purpose and scope 6
    Previous investigations 6
    Acknowledgments 7
Hydrogeologic setting 8
    Geologic units 8
    Aquifer and confining units 8
    Ground-water source and occurrence 16
Water levels 16
    Surficial and Yorktown aquifers 17
    Pungo River aquifer 17
    Castle Hayne aquifer 19
Quality of water from supply wells 23
    Sample collection 24
    Sample analysis 27
    Inorganic constituents 30
        Major cations and anions 30
        Nutrients 30
        Metals 35
        Other constituents 35
        Results 38
    Organic constituents 38
        Priority pollutant organic compounds and organic pesticides 38
        Nonpriority pollutant organic compounds 42
        Results 44
Summary and conclusions 46
References 48
Basic data 53

ILLUSTRATIONS

Page

Plate 1. Hydrogeologic sections A-A' and B-B', U.S. Marine Corps Air Station, Cherry Point, North Carolina .... In pocket

Figure 1. Map of location of U.S. Marine Corps Air Station, Cherry Point, North Carolina, and generalized geologic section of the Coastal Plain 3
2. Map of location of drinking-water supply wells and hazardous-waste disposal and spill sites, U.S. Marine Corps Air Station, Cherry Point, North Carolina 4
3. Hydrogeologic section of aquifers and confining units in parts of Jones, Craven, and Carteret Counties, North Carolina 10
4. Map of location of selected wells and hydrogeologic sections, U.S. Marine Corps Air Station, Cherry Point, North Carolina 11
5. Typical relation between geologic and hydrologic units saturated with freshwater, U.S. Marine Corps Air Station, Cherry Point, North Carolina 12

Page

6-9. Maps of:
  6. Estimated total thickness of confining units between land surface and the top of the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina 15
  7. Approximate altitude of the water table, U.S. Marine Corps Air Station, Cherry Point, North Carolina 18
  8. Approximate altitude of the potentiometric surface of the Castle Hayne aquifer, fall 1941, U.S. Marine Corps Air Station, Cherry Point, North Carolina 20
  9. Approximate altitude of the potentiometric surface of the Castle Hayne aquifer, March 24-27, 1987, U.S. Marine Corps Air Station, Cherry Point, North Carolina 22

10. Hydrograph of Well 26 (MCAS Well 20), from August 1986 to February 1987, U.S. Marine Corps Air Station, Cherry Point, North Carolina 23

11. Trilinear diagram of major cations and anions in water from wells in the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina 34

12-14. Maps of:
  12. Concentrations of lead in water from wells in the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina 36
  13. Concentrations of nickel in water from wells in the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina 37
  14. Concentrations of benzene in water from wells in the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina 41

TABLES

Page

Table 1. Generalized relation between geologic and hydrogeologic units in the Coastal Plain of North Carolina 9
2. Records of selected wells 54
3. Chemical analyses of water from wells in the Castle Hayne aquifer 59
4. U.S. Environmental Protection Agency list of priority pollutants 29
5. Selected statistics for water-quality characteristics of water from wells in the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina 31
6. Priority pollutant organic compounds and organic pesticides detected in water from wells in the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina 39
7. Nonpriority pollutant organic compounds detected in water from wells in the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina 43
8. Total number of organic chemicals identified in water from wells in the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina 45

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ABSTRACT

The U.S. Marine Corps Air Station, Cherry Point, North Carolina, is located in southeastern Craven County in the Coastal Plain physiographic province. The Air Station is underlain by four freshwater-bearing aquifers that are composed primarily of sand and sandy limestone to a depth of about 500 feet below land surface. The sediments are saturated with saline water below this depth. The aquifers are separated from each other by three confining units with an aggregate thickness that ranges from over 70 feet in the north-central part of the Air Station to less than 20 feet in the southern part of the area where these units are thin and (or) discontinuous.

Water supply is obtained from wells that tap the Castle Hayne aquifer at a depth of 195 to 330 feet below land surface. Many of the water-supply wells are located near numerous landfill sites that have been used to dispose of all kinds of wastes generated at the Air Station, including considerable amounts of hazardous wastes. A number of spill sites are also present in the same general area as the water-supply wells and landfills.

Large ground-water withdrawals for more than 45 years have lowered the potentiometric surface in the Castle Hayne aquifer 5 to 10 feet regionally and as much as 30 feet at some of the active production wells. The water-level declines have created a potential for downward movement of contaminated ground water from the surficial and Yorktown aquifers, through the Pungo River aquifer and to the Castle Hayne aquifer, and a potential for upward movement of saline water from the deep part of the aquifer system.

Chemical analyses of water from the supply wells indicate that the raw water from the Castle Hayne is a hard, calcium-bicarbonate type with a median dissolved-solids concentration of 300 milligrams per liter and median pH of 7.25. Excessive concentrations of iron and manganese (median of 0.78 and 0.08 milligrams per liter, respectively) are common. Excessive concentrations of lead and (or) nickel, as much as 0.4 milligrams per liter each, were detected in water from three wells. These occurrences possibly indicate contamination, but duplicate analyses are needed to verify these metal concentrations. Data on chloride concentrations for the deepest operating supply well indicate that chloride has increased from 10 milligrams per liter to more than 40 milligrams per liter over a 45-year period.

Two general areas of organic ground-water contamination were identified in the Castle Hayne aquifer. Benzene concentrations range from 0.5 to 1.9 micrograms per liter in water from the Castle Hayne aquifer over an area of about 1 square mile in the southern part of the Air Station. The concentrations occurred in water from wells near or adjacent to Sandy Branch where the confining units are thin and discontinuous; and, consequently, a good hydraulic connection is indicated between land surface and the Castle Hayne aquifer in this area. All benzene concentrations were below the 5 micrograms per liter maximum contaminant level set by U.S. Environmental Protection Agency for drinking water.

A second area of ground-water contamination in the Castle Hayne aquifer was identified north of Sandy Branch near the intersection of Roosevelt Boulevard and Slocum Road. Contamination in this area is in the form of a variety of extractable organic compounds generally classified as fatty acids and their derivatives. These compounds are not priority pollutants. The occurrence of this contamination generally coincides with an area of known spills, waste oil storage site, tank farms, waste incinerator, and the largest landfill on the Air Station. Concentrations of these nonpriority pollutant organic compounds in water samples were as high as 28 micrograms per liter.

The occurrence of benzene and fatty acids in water from the Castle Hayne aquifer indicates the vulnerability of the aquifer to contamination by relatively mobile organic compounds. In addition, their occurrence may be the precurser to contamination by slower moving organic compounds in the future.

INTRODUCTION

Location and Background

The U.S. Marine Corps Air Station, Cherry Point, North Carolina is located in the Coastal Plain physiographic province of the State, in southeastern Craven County (fig. 1). The Air Station includes an area of about 19 mi^2 just north of the Town of Havelock and is bounded on the north by the Neuse River estuary, the east by Hancock Creek, the south by North Carolina Highway 101, and the west by an irregular north-south line located about 0.75 mi west of Slocum Creek (fig. 2).

The Air Station relies solely on ground water for water supply and at present uses between 2.5 and 4.5 Mgal/d. Since it opened in 1941, the Air Station's water supply has been derived from about 20 supply wells that range from 195 to 330 feet in depth. Each well is equipped to pump about 200 gal/min, and the number of wells being used changes from less than half to all available as water needs change or fluctuate at the Air Station. The supply wells tap the upper half of a thick, sandy limestone (Castle Hayne aquifer), the top of which occurs at about 115 ft below land surface in the area.

Considerable amounts and various kinds of hazardous wastes from aircraft refitting and manufacturing operations at the Air Station have been spilled or disposed of at numerous landfill sites (fig. 2). The landfill sites, some in use for over 40 years, lack natural or synthetic seepage barriers. Consequently, ground water has been contaminated around many of the sites (NUS Corp., 1985, 1986, and 1987).

Most of the disposed wastes and spills are near many of the wells that supply the water for the Air Station (fig. 2). Ground-water withdrawals pumped from the water-supply wells (2.5 to 4.5 Mgal/d) have lowered the potentiometric surface of the Castle Hayne aquifer so that it is lower than the water table in the surficial and Yorktown aquifers over a much larger area than that which occurred in 1941. Thus, a potential exists for the downward movement of contaminated water from the surficial and Yorktown aquifers to the deeper aquifers including the Castle Hayne aquifer, the source of water for the supply wells.

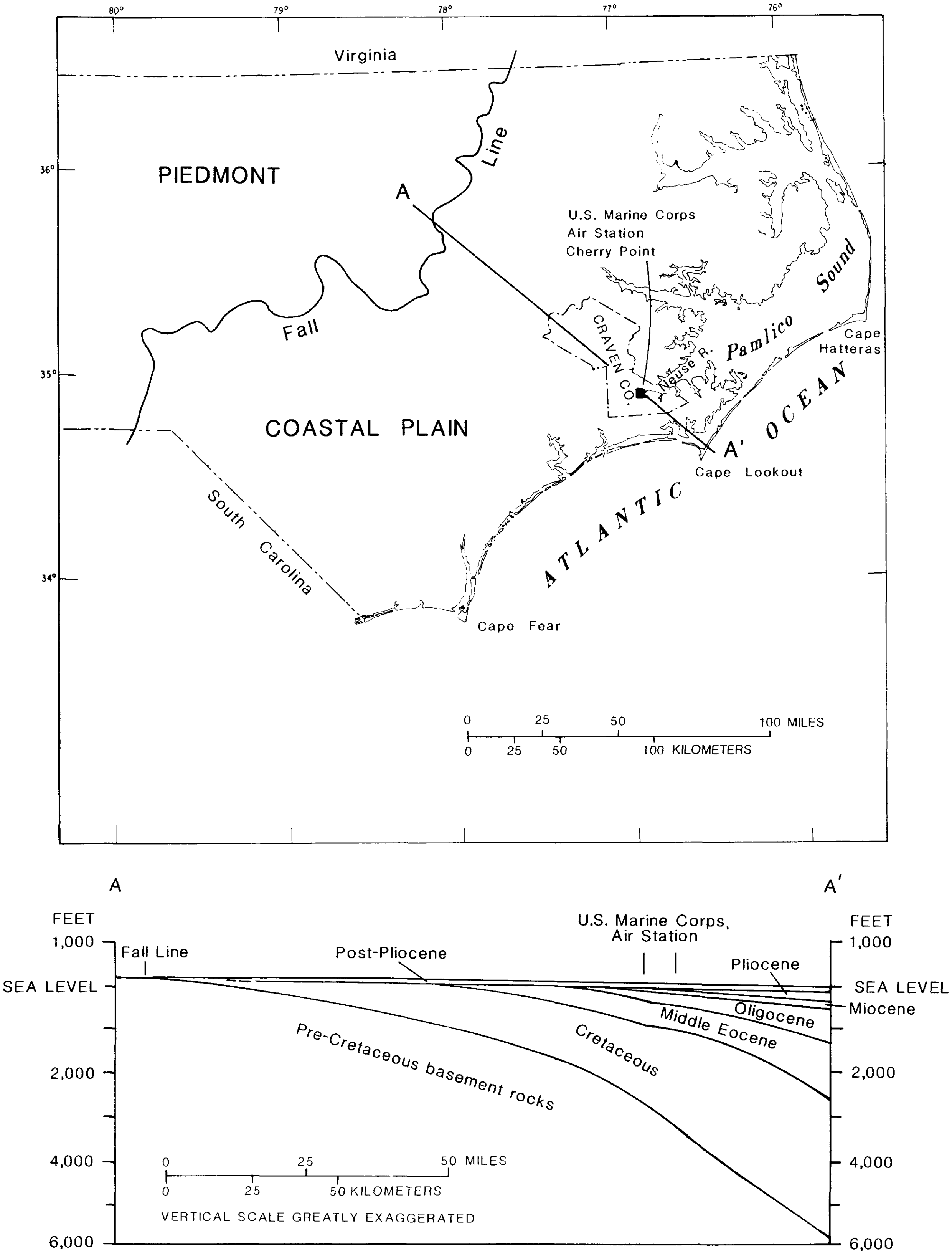

Figure 1.--Location of U.S. Marine Corps Air Station, Cherry Point, North Carolina, and generalized geologic section of the Coastal Plain.

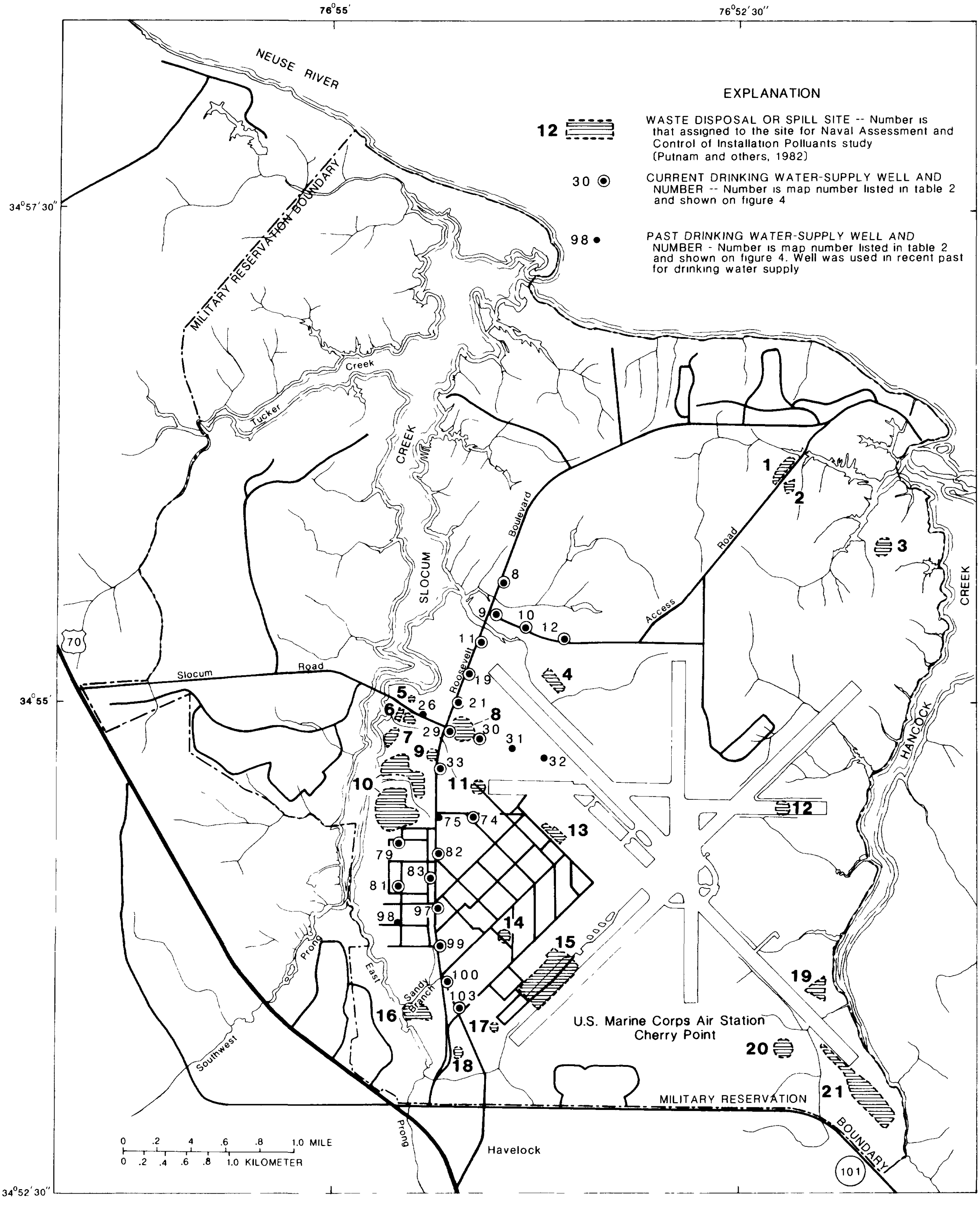

Figure 2.--Location of drinking-water supply wells and hazardous-waste disposal and spill sites, U.S. Marine Corps Air Station, Cherry Point, North Carolina.

In addition to the potential for contamination from hazardous wastes, the presence of saline water (water with chloride concentrations greater than 250 mg/L (milligrams per liter)) in the lower part of the supply aquifer is also a threat to the Air Station's water supply. The saline water has the potential to encroach into the freshwater part of the supply aquifer.

The nature and extent of contamination at most of the sites shown in figure 2 is being studied and reported to the Air Station by private consulting firms. These studies are part of the Department of Defense Installation Restoration program for the inventory and appropriate remediation of hazardous-waste disposal and spill sites at all U.S. military installations. Each branch of the armed forces has devised similar operational programs to meet the objectives of the overall program. The Navy and Marine Corps studies are being performed under the Navy Assessment and Control of Installation Pollutants (NACIP) program (Putnam and others, 1982).

The term "hazardous-waste site" as used in this report refers to past hazardous-waste disposal and spill sites at the Air Station identified under the Installation Restoration (formerly NACIP) program, and to some hazardous-waste disposal sites currently regulated under the Resource Conservation and Recovery Act (RCRA). However, the term does not refer to or include the many sites currently regulated under RCRA that are used to store hazardous wastes until they can be picked up and transported to a licensed disposal site off the Air Station. These storage sites are properly managed and would not, under normal circumstances, be considered as a source of contamination.

Growing water-supply needs reported by the Air Station and the threat of contamination to the Castle Hayne aquifer by disposed or spilled wastes or by saline water prompted a study by the U.S. Geological Survey (Survey) in cooperation with the U.S. Marine Corps (USMC) of the ground-water resources of the Air Station. Thus, in April 1986, the Survey started a 4-year study to evaluate (1) the quality of ground water being pumped from the water-supply wells that tap the Castle Hayne aquifer at the Air Station, (2) the potential for contamination of the Castle Hayne aquifer by hazardous and toxic wastes that occur at various surface disposal and spill sites at the Air Station and by saline water that occurs in the lower part of the Castle Hayne aquifer, and (3) alternative ground-water use and management practices that will help reduce the chances for contamination of the Castle Hayne aquifer and the water-supply wells.

The study has been divided into three phases with the following specific objectives to complete the three goals outlined above:

1. Phase I work objectives are to appraise (1) the hydrogeologic setting, the distribution of aquifers and confining units, from geophysical and lithologic logs of the supply wells tapping the Castle Hayne aquifer, (2) the hydraulic head distribution and general directions of ground-water flow within and between the freshwater aquifers that underlie the Air Station, and (3) the quality of water from supply wells tapping the Castle Hayne aquifer. Phase I work extended over a 1-year work period ending July 31, 1987.

2. Phase II work will extend over a 2-year period ending July 31, 1989. Phase IIa (the first year) work objectives are to drill test wells to obtain additional data needed to define (1) the hydrogeologic framework, (2) the hydraulic characteristics of the aquifers and confining units, (3) the hydraulic head distribution, and (4) the water-quality characteristics of the aquifers that underlie the Air Station.

   Phase IIb (second year) work objectives are to (1) finish any necessary test drilling, (2) make geophysical logs in the test wells, (3) analyze lithologic and water-quality samples collected from test wells, (4) make water-level measurements and aquifer tests in test wells, and (5) use all new data to refine knowledge of the hydrogeologic framework, hydraulic characteristics of aquifers and confining units, hydraulic head distribution within and between aquifers and confining units, and water-quality characteristics of the aquifers.

3. Phase III work objectives are to use all previously collected and analyzed data to construct a finite-difference, ground-water flow model of the hydrogeologic system in and around the Air Station that can be used to help guide site selection for new supply wells regarding reduced well interference and reduced potential for contamination of the water supply. Phase III work will extend over a 1-year period ending July 31, 1990.

Purpose and Scope

The purpose of this report is to describe the results and present data for Phase I of the ground-water resources study. The report describes, insofar as the present data base would allow, (1) the hydrogeologic setting (the occurrence of ground water and distribution of aquifers and confining units), (2) the distribution of hydraulic head (water levels) within and between the aquifers, and (3) the quality of water from 21 supply wells at the Air Station. The descriptions and interpretations that follow are primarily from a study of data obtained from chemical analyses of water samples, water-level measurements, geophysical logs, and available lithologic and drillers' logs for 24 deep wells, and water-level measurements from 54 shallow water-level observation/water-quality monitoring wells on the Air Station. Emphasis is placed on the western half of the Air Station where the greatest number of water-supply wells and waste sites are located.

Previous Investigations

Several reports contain information about the hydrogeologic framework, the water levels, and the quality of ground water at the Air Station. The reports that were most helpful during the preparation of this report are reviewed briefly below.

Reports by LeGrand (1960), Floyd (1969), and Floyd and Long (1970) include information on the characteristics and quality of water from supply wells at the Air Station and describe the general geology and ground-water resources of the Craven County area. Kimrey (1965) and Miller (1982) describe the characteristics of the Pungo River Formation, which constitutes an important part of the hydrogeologic framework at the Air Station. Brown and others (1972) describe the geology and permeability distribution of the sedimentary rocks of the North Carolina Coastal Plain and, thus, those that occur beneath the Air Station as part of a regional study of the Atlantic Coastal Plain from North Carolina to New York. Robison and Mann (1977) describe the characteristics and the general quality and quantity of water pumped from the supply wells at the Air Station. Black and Veatch, Inc., (1982) describe the construction characteristics and yield of the water-supply wells at the Air Station.

As part of the Naval Assessment and Control of Installation Pollutants (NACIP) program, Putnam and others (1982) describe the location and estimated contents and constituents of all hazardous-waste disposal and spill sites at the Air Station. The 1982 study determined which of the sites were most likely to constitute a hazard to the environment and the water resources at the Air Station and recommended them for study in further detail to confirm the extent and nature of contamination. NUS Corporation (1984, 1985, and 1986) describes a plan for and the results of sampling surface water, soil, and ground water to determine the exact nature and extent of the contamination around the hazardous-waste disposal and spill sites that were selected for confirmation studies.

Schnabel Engineering Associates (1981), N.B. Sharpless and R.W. Coble (U.S. Geological Survey, written commun., 1983), and NUS Corporation (1987) describe the hydrogeologic framework, water-bearing and water-yielding properties, water levels, and the inferred directions and rates of ground-water movement in the sediments that occur between land surface and about 100 ft below land surface near two small industrial waste sludge pits at the Air Station.

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The authors are particularly indebted to R.D. Nelson, David Criswell, and Gary Edwards of the MCAS Natural Resources and Environmental Affairs Department for help in planning and implementing the logistical support that was vital to the collection of water samples, water levels, and geophysical logs from existing water-supply and observation wells; the supervisory staff and the many plumbers, electricians, and crane operators of the MCAS Facilities Maintenance Department who arranged for and pulled and reset pumps so that water samples, water levels, and geophysical logs could be obtained from the water-supply wells; and P.G. Fisher, Facilities Engineering Department, Civil Division, MCAS, Cherry Point, for providing valuable data on the locations and characteristics of wells that were drilled at the Air Station from 1941 to present.

HYDROGEOLOGIC SETTING

Geologic Units

The Air Station is underlain by about 2,500 ft of interbedded, unconsolidated to partially consolidated sedimentary deposits of sand, silt, clay, shell, and limestone that range in age from Cretaceous to Holocene (Brown and others, 1972; American Association of Petroleum Geologists, 1983). These deposits are part of the Coastal Plain rocks of North Carolina that, in aggregate, form a wedge-shaped mass that thickens from a featheredge at the Fall Line to as much as 10,000 ft at Cape Hatteras (Brown and others, 1972, pl. 5). The Coastal Plain deposits are underlain by igneous and metamorphic rocks (Daniels and Leo, 1985) similar to those exposed at land surface in the Piedmont province west of the Fall Line. A generalized cross section of the Coastal Plain sedimentary deposits drawn from the Fall Line through the Air Station to the Atlantic Ocean near Cape Lookout is shown in figure 1.

The sedimentary deposits that underlie the Air Station have been divided according to their age and lithology into a number of geologic units. Table 1 shows the names and relations of the geologic units to one another and the hydrogeologic units into which the deposits have been further divided.

Aquifer and Confining Units

The sedimentary deposits have been divided according to their hydrologic characteristics into a number of mappable hydrologic entities called aquifers and confining units (table 1). An aquifer may be composed of a formation, a group of formations, or part of a formation that contains a preponderance of saturated permeable material (sand and limestone in the Air Station area) that will yield significant quantities of water to wells. An aquifer may be composed of interconnected, saturated permeable material of different age.

In general, aquifers are adjacent to confining units, which are mostly composed of material that has low permeability (clay in the Air Station area). Confining units will not yield significant amounts of water to wells, and they also may be composed of material of different age.

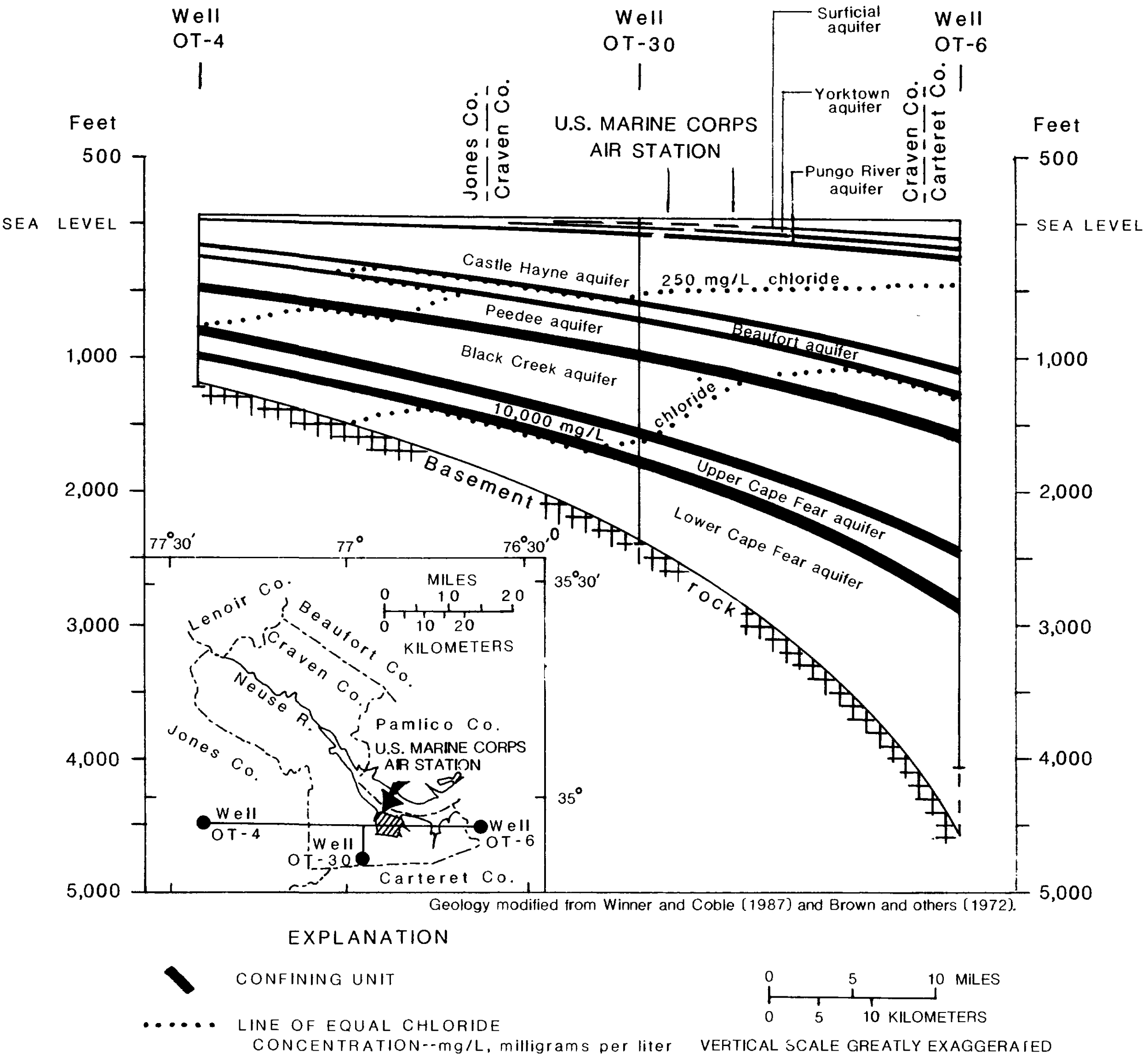
The general regional distribution of aquifers and confining units and the underlying basement rocks, in an east-west section drawn through the Air Station from Jones County to Carteret County, are shown in figure 3. Four aquifers and three confining units separating them beneath the Air Station are saturated or partly saturated with freshwater. The actual depth of the freshwater/saline-water (250 mg/L chloride concentration) boundary beneath the Air Station remains to be determined; however, it is estimated to be between 450 and 550 ft below sea level, which places the boundary within the Castle Hayne aquifer (Winner and Coble, 1987).

A more detailed description of the upper 300 ft of the aquifers and confining units that occur beneath the Air Station is possible from a study of data available from wells drilled there in the past. For this purpose, 115 selected wells were inventoried and mapped. The locations of these wells are shown in figure 4, and the characteristics of and the available data for the wells are listed in table 2 at the back of this report.

Table 1.--Generalized relation between geologic and hydrogeologic units in the Coastal Plain of North Carolina (Modified from Winner and Coble, 1987)

Geologic units			Hydrogeologic units
System	Series	Formation	Aquifer and confining unit
Quaternary	Holocene Pleistocene	Undifferentiated	Surficial aquifer
Tertiary	Pliocene	Yorktown Formation	Confining unit
			Yorktown aquifer
	Miocene	Eastover Formation[1]	Confining unit
		Pungo River Formation	Pungo River aquifer
		Belgrade Formation[1]	Confining unit
	Oligocene	River Bend Formation	Castle Hayne aquifer
	Eocene	Castle Hayne Formation	Confining unit
	Paleocene	Beaufort Formation	Beaufort aquifer
Cretaceous	Upper Cretaceous	Peedee Formation	Confining unit
			Peedee aquifer
		Black Creek and Middendorf Formations	Confining unit
			Black Creek aquifer
		Cape Fear Formation	Confining unit
			Upper Cape Fear aquifer
			Confining unit
			Lower Cape Fear aquifer
	Lower Cretaceous[1]	Unnamed deposits[1]	Confining unit
			Lower Cretaceous[1] aquifer
Pre-Cretaceous basement rocks			

[1] Geologic and hydrologic units probably not present beneath Air Station.



Geology modified from Winner and Coble (1987) and Brown and others (1972).

Figure 3.--Hydrogeologic section of aquifers and confining units in parts of Jones, Craven, and Carteret Counties, North Carolina.

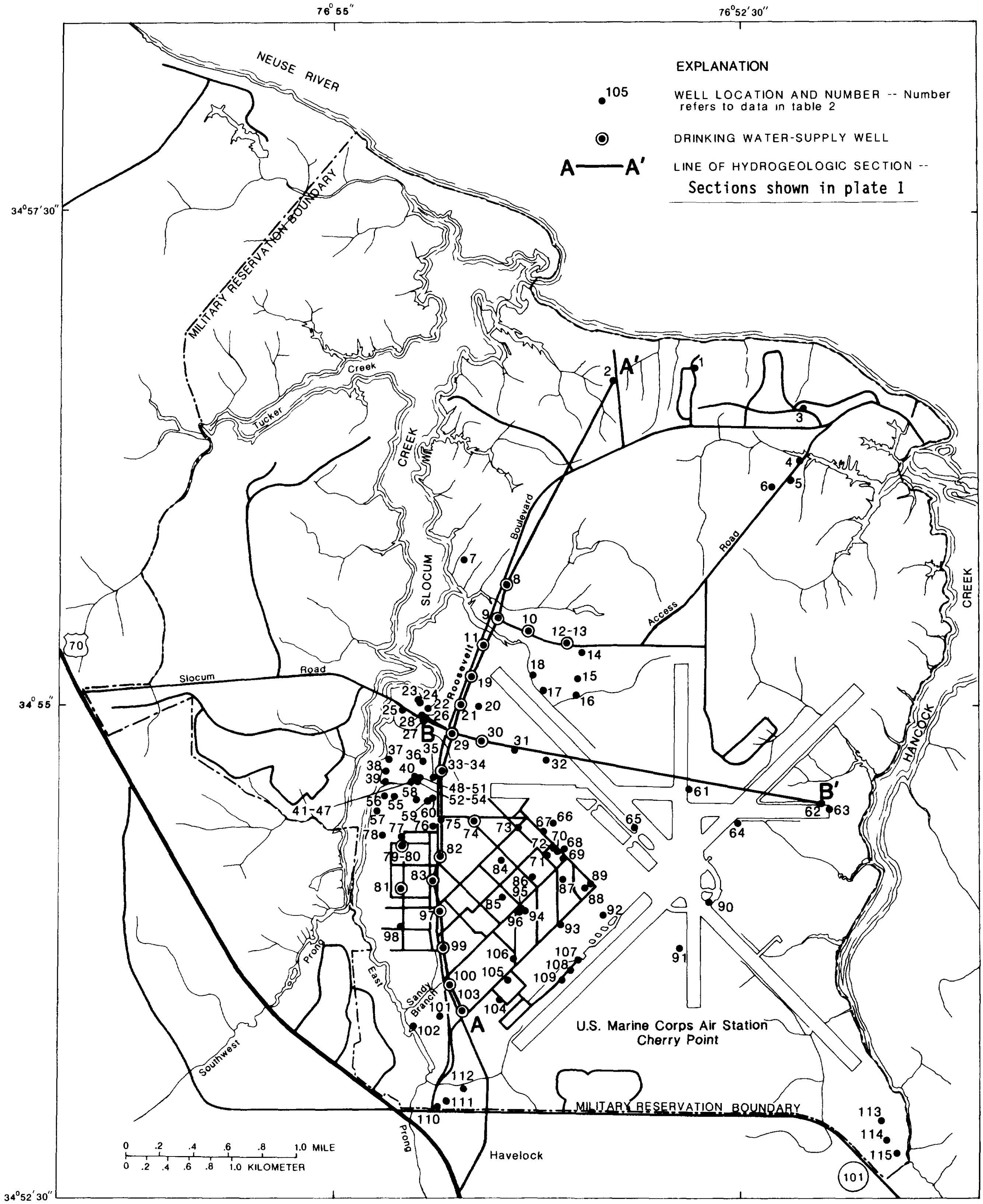


Figure 4.--Location of selected wells and hydrogeologic sections, U.S. Marine Corps Air Station, Cherry Point, North Carolina.

A typical section of the upper 300 ft of the aquifers and confining units at the Air Station is shown in figure 5. The sedimentary rocks that underlie the area, from youngest to oldest, are the undifferentiated sands, silts, and clays of post-Pliocene age; the sands, silts, clays, and shell beds of the Pliocene Yorktown Formation; the phosphatic sands, silts, clays, and indurated sandy limestone beds of the Miocene Pungo River Formation; and the sand, sandy limestone, and molluskan cast and mold limestone of the Oligocene River Bend Formation and Eocene Castle Hayne Formation.

The surficial aquifer is composed of the sand and silty sand of the post-Pliocene deposits. The Yorktown aquifer is separated from the surficial aquifer by the clay beds of a confining unit in the central part of the area. In the northern and eastern parts of the area, this confining unit is missing. Here the Yorktown aquifer, composed of the sands of the Yorktown Formation, is directly overlain by the sands of the surficial aquifer, and they function as a single hydrologic unit.

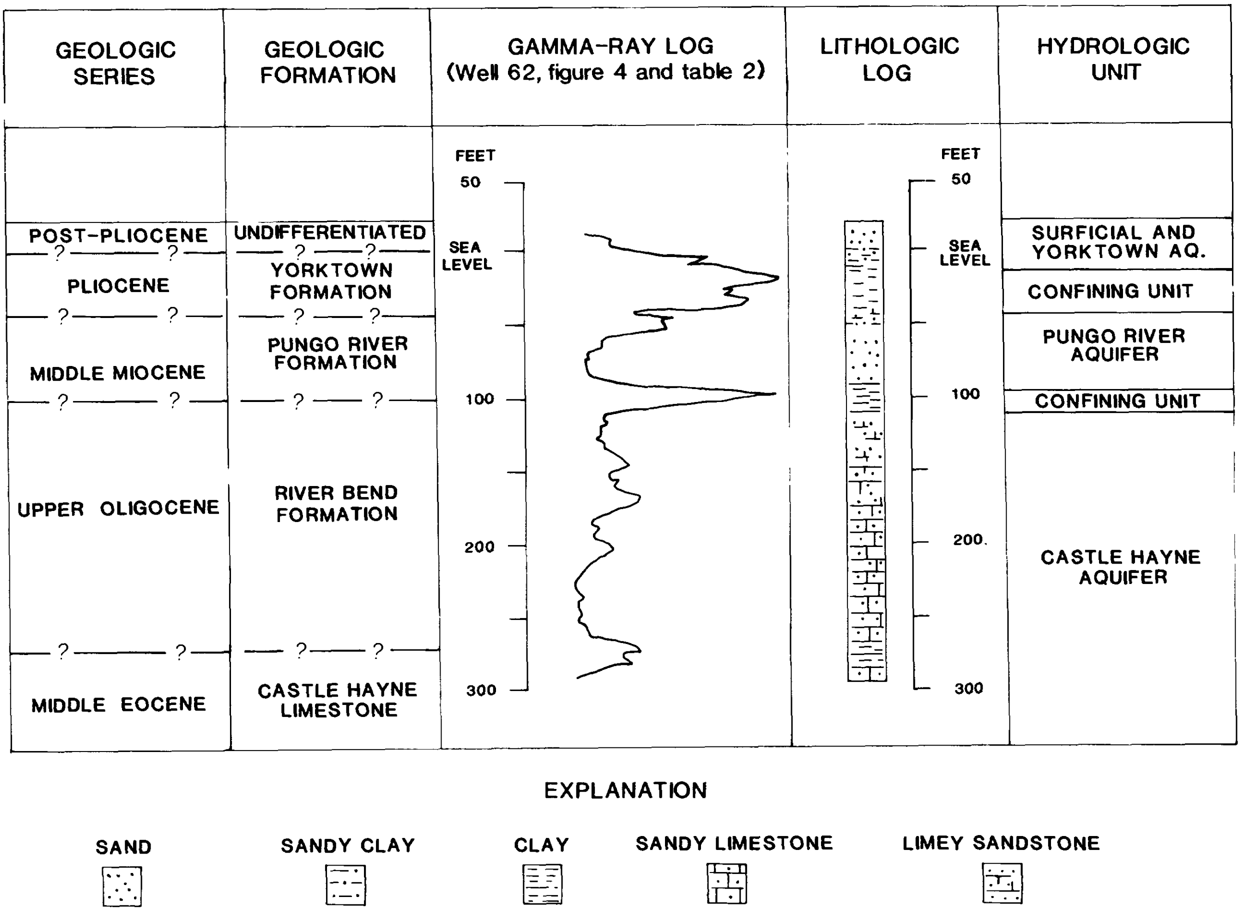


Figure 5.--Typical relation between geologic and hydrologic units saturated with freshwater, U.S. Marine Corps Air Station, Cherry Point, North Carolina.

The Yorktown aquifer is underlain by a confining unit composed of clay and silty clay beds in the Yorktown Formation and the upper part of the underlying Pungo River Formation. The Pungo River aquifer is composed of phosphatic sands in the lower part of the Pungo River Formation. The Pungo River aquifer is underlain by a confining unit composed of silty clay beds in the lower part of the Pungo River and the upper part of the River Bend Formations. The Castle Hayne aquifer, the water-supply aquifer at the Air Station, is composed of the sand, sandy limestone, and cast and mold molluskan limestone beds of the River Bend and the Castle Hayne Formations.

In addition to showing the relation between the lithology, geologic formations, and aquifers and confining units, figure 5 shows the relation of these units to the natural gamma ray log. These relations were used to construct the hydrogeologic sections described below.

The estimated transmissivity of the aquifers is shown in the following table:

Hydrologic unit	Transmissivity[1/] in ft^2/day
Surficial and Yorktown aquifers combined	800
Pungo River aquifer	500
Castle Hayne aquifer	35,000

These estimates are made from data available from the Regional Aquifer System Analysis (RASA) study of the North Carolina Coastal Plain (Winner and Coble, 1987). These values will be refined from aquifer tests data that will be collected during Phase II of the study.

Two hydrogeologic sections shown in plate 1 are used to display the details of the aquifer and confining units in the upper 300 ft. These sections were compiled primarily from natural gamma-ray geophysical logs made in 24 wells, and from available lithologic logs. No resistance or resistivity logs were made because the wells are cased with steel pipe. Because of this the natural gamma-ray logs, some of which are selectively shown on the sections, are most useful to distinguish between the clay confining material and the sand and limestone aquifer material at the Air Station. In general, clay emits higher concentrations of gamma radiation than sand and limestone. The higher the gamma radiation emission, the farther to the right the log deflection.

It is here noted that among other minerals, collophanite, the phosphate mineral found in the Pungo River Formation in eastern North Carolina, also emits a substantial amount of gamma radiation (Kimrey, 1965; Miller, 1982). Thus, because the Pungo River Formation occurs beneath the Air Station, it

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[1/] Rate at which water (at the prevailing viscosity) is transmitted through a unit width of the saturated thickness of the aquifer under a unit hydraulic gradient.

remains to be determined (from an examination of core samples) how much of the radiation is caused by phosphate mineral or clay, or both. It is possible that the radiation from phosphatic sand could be mistaken for confining material that does not exist. However, because of fair agreement between available lithologic logs and the natural gamma-ray logs, it is assumed at present that the high gamma radiation is caused by clay and indicates a confining unit.

Sections A-A' and B-B' (pl. 1) indicate that the upper 30 to 50 ft of the sediments underlying the area comprise the surficial and Yorktown aquifers. At places, particularly in the central part of the area, these aquifers are separated by a confining unit. However, these aquifers probably act as one unit in other places where the intervening confining unit is thin and discontinuous, as in the northern and eastern part of the Air Station and, for purposes of later analyses, will be considered as one unit.

The sections (pl. 1) also show the thickness and extent of all the aquifers and confining units from the Yorktown to the Castle Hayne aquifer. The Yorktown aquifer is underlain by a confining unit. The thickness of this confining unit ranges from 0 to 35 ft and averages about 20 ft (pl. 1). A sand that underlies this confining unit comprises the Pungo River aquifer in the area. The thickness of this aquifer ranges from 17 to 45 ft and averages about 30 ft. The Pungo River aquifer is underlain by another confining unit. The thickness of this confining unit ranges from 0 to 30 ft and averages about 20 ft. This confining unit separates the Pungo River from the Castle Hayne aquifer. The Castle Hayne aquifer, the water-supply aquifer at the Air Station, is composed of unconsolidated to consolidated sand and sandy limestone. The top of this aquifer ranges from 100 ft below land surface in Well 26 (MCAS Well 20) to 125 ft below land surface in Well 62, increasing in depth toward the east. The average depth to the top of this unit is about 115 ft below land surface.

The confining units, which separate the Castle Hayne aquifer (pl. 1) from the sources of contamination in the surficial deposits, occur between land surface and about 115 ft below land surface. The surficial deposits here may include parts of the surficial and (or) Yorktown aquifers, and the unsaturated zone above these aquifers. Two and three confining units occur in this interval from place to place. The aggregate thickness of these confining units ranges from about 20 ft in the southern part of the area to more than 70 ft in the north-central part (fig. 6). Thus, these confining units constitute from about one-fifth to two-thirds of this interval in these areas, respectively.

As shown on section A-A' (pl. 1), all the confining units appear to be discontinuous in the southern part of the area. Even though all the confining units are not interpreted to be missing at any one place, this discontinuity affords the best natural hydraulic connection that has been found between the Castle Hayne aquifer and land surface at the Air Station. The most direct connection is near Well 100 (MCAS Well 16), in the area where Sandy Branch cuts through the uppermost confining unit (pl. 1). Thus, there is the potential for any contaminated ground water that may occur in the surficial deposits in this area to move more easily into the Castle Hayne aquifer. Additional data may reveal other such discontinuities on the Air Station.

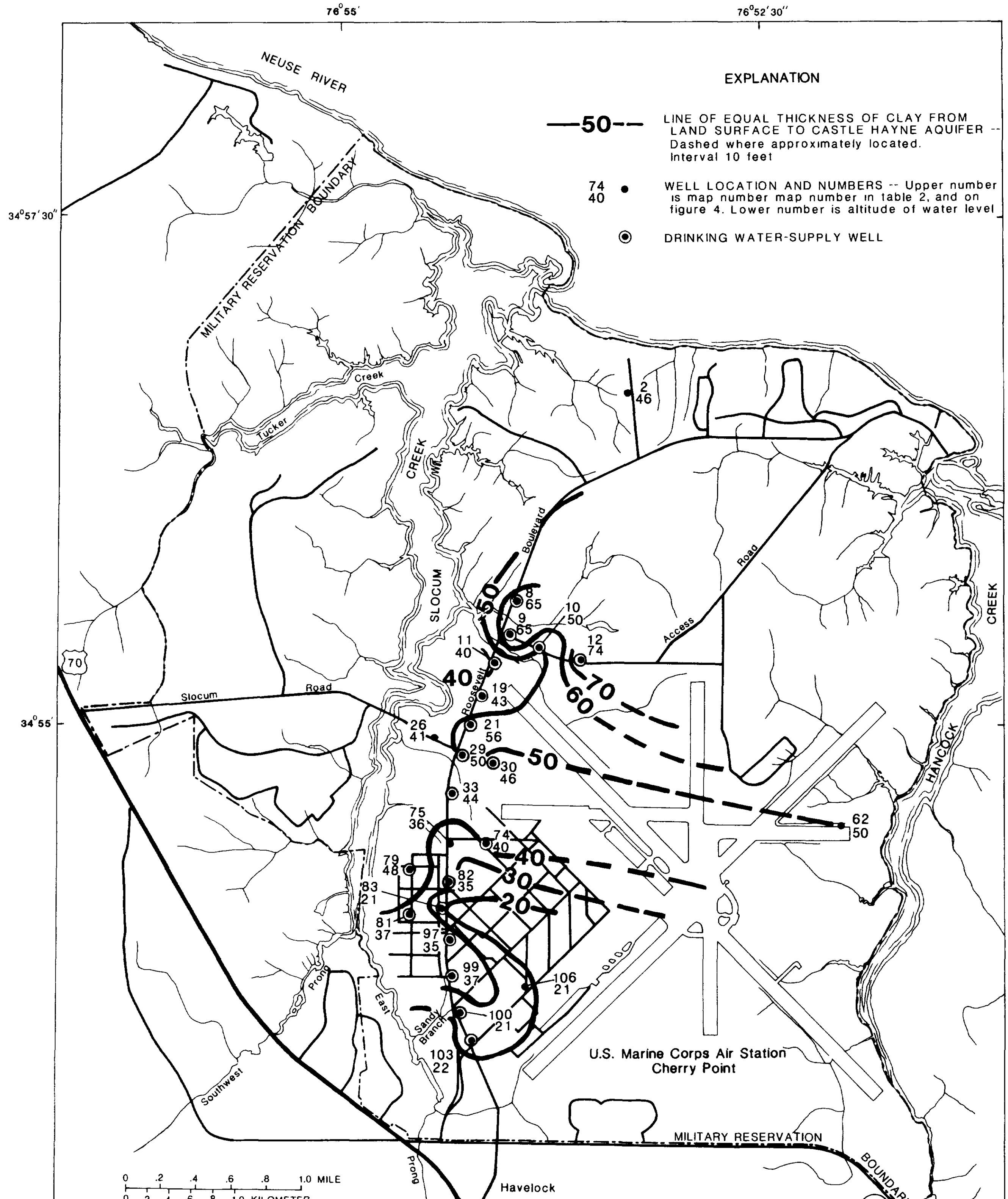

Figure 6.--Estimated total thickness of confining units between land surface and the top of the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina.

Ground-Water Source and Occurrence

All the sedimentary deposits from the top of the basement rocks to about 15 ft below land surface (the approximate maximum depth to the water table at the Air Station) are saturated with ground water. The water occurs in and moves through the void spaces within the sedimentary deposits.

The ground water that occurs between land surface and about 500 ft below land surface is freshwater containing chloride concentrations less than 250 mg/L. For the purposes of this report, saltwater is defined as water containing chloride concentrations of 250 mg/L or more. The chloride concentrations increase with increasing depth and may be as much as 19,000 mg/L (seawater concentrations) near the bottom of the sedimentary deposits beneath the Air Station. The source of the freshwater is precipitation; seawater occurs naturally in marine sediments as a condition of their deposition.

About 20 percent (11 in.) of the average annual precipitation at the Air Station is estimated to infiltrate to the water table, the top of the zone of saturation, and enters the ground-water system. This estimate is made from data reported by Winner and Simmons (1977) for an area in northern Craven County which is underlain by the same geologic formations that occur beneath the Air Station. Heath (1983, p. 14) describes the movement of water through the ground-water system, such as the Air Station, as follows, "Water enters the ground-water system in recharge areas and moves through them, as dictated by the hydraulic gradients and hydraulic conductivities, to discharge areas.... In the humid part of the country, recharge occurs in all interstream areas--that is, in all areas except along streams and their adjoining flood plains. The streams and flood plains are, under most conditions, discharge areas."

The ground water in the zone of saturation occurs under confined and unconfined conditions. It occurs under unconfined conditions only in shallow aquifers, such as the surficial and the upper part of the Yorktown aquifers where there are no confining units between the water table and land surface. Under these conditions, the ground-water is at atmospheric pressure at the water table; the water table is free to rise and fall, and its altitude can be determined from water levels measured in shallow wells that tap the aquifer at or just below the water table. Ground water occurs under confined conditions in deeper aquifers that are confined above and below by layers of low-permeability material like clay. Under these conditions, the water in a tightly cased, nonpumping well will stand above the top of the aquifer; this water level defines a point on the potentiometric surface of the aquifer.

WATER LEVELS

The water levels that define the hydraulic heads, hydraulic gradients, and the directions of flow within and between the units are the subjects of this section. The ground water that saturates the aquifers and confining units beneath the Air Station moves through the intergranular spaces in these units in response to differences in hydraulic head. The rate and direction of this movement is controlled by the hydraulic conductivity and effective porosity of the units, which is their ability to transmit water, and by the hydraulic gradient, which is the difference in the hydraulic head within and between the units. In general, ground water flows from areas where hydraulic head is high to areas where it is low.

Water-level data from 115 wells (fig. 4 and table 2) were evaluated to determine the direction of ground-water flow. These data included records from a water-level recorder installed on Well 26 (MCAS Well 20), and water-level measurements that were made in about 80 wells in March 1987. Enough historical data were available to construct a generalized map of the potentiometric surface of the Castle Hayne aquifer for the fall of 1941 when many of the water-supply wells were drilled. Also, maps were constructed for the present-day (1987) potentiometric surface for the Castle Hayne aquifer and the Yorktown and surficial aquifers. Data are not sufficient to map the potentiometric surface in the Pungo River aquifer; however, enough information is available to make comparisons of hydraulic head between the aquifers at landfill site 10 (fig. 2).

Surficial and Yorktown Aquifers

The approximate altitude of the water table (top of the zone of saturation, which occurs in the surficial and Yorktown aquifers) at the Air Station is shown in figure 7. The map was constructed from water-level measurements made during the period from March 24-27, 1987, in 54 wells that tap the surficial and Yorktown aquifers, and from the altitude of small streams determined from topographic maps of the area. Not all 54 measurements were plotted on the illustration because many measurements were taken in wells near one another and had very similar head values (table 2).

The average altitude of the water table in the study area is estimated at about 15 ft above sea level and ranges from more than 25 ft above sea level just west of the Air Station boundary and south of Slocum Road to about 1 ft above sea level near the tidal reaches of Slocum and Hancock Creeks and the Neuse River. Water levels in the surficial and Yorktown aquifers are estimated to be higher than 20 ft above sea level in two small areas along the western boundary of the Air Station and in one small area in the northern part of the peninsula between Access Road and Roosevelt Boulevard. It might be expected that water levels slightly higher than 20 ft above sea level would occur on the central part of the peninsula where the runways and the taxiways are located. It is here assumed that the water table in this area was probably somewhat higher prior to the construction of the large paved areas and the artificial drainageways used to facilitate rapid runoff and that the reduced water-table altitude is thus a result of reduced ground-water recharge in this area. For the purpose of comparison, land-surface elevations range from between 25 and 30 ft above sea level on the highest interstream areas to near sea level adjacent to Slocum and Hancock Creeks and the Neuse River.

Ground-water movement in the surficial and Yorktown aquifers is away from the areas of high hydraulic head toward the streams and creeks. The direction of movement is perpendicular to the water-table contours. The configuration of the water-table contours in the southwestern part of the peninsula indicates that most of the ground-water movement from the major industrial area at the Air Station is toward Sandy Branch.

Pungo River Aquifer

Data are not sufficient to map the potentiometric surface and direction of ground-water flow in the Pungo River aquifer, but enough water-level information is available to make a comparison of heads between the aquifers at waste-disposal site 10 (fig. 2). The following table illustrates that the water level in the Pungo River aquifer is intermediate between those in

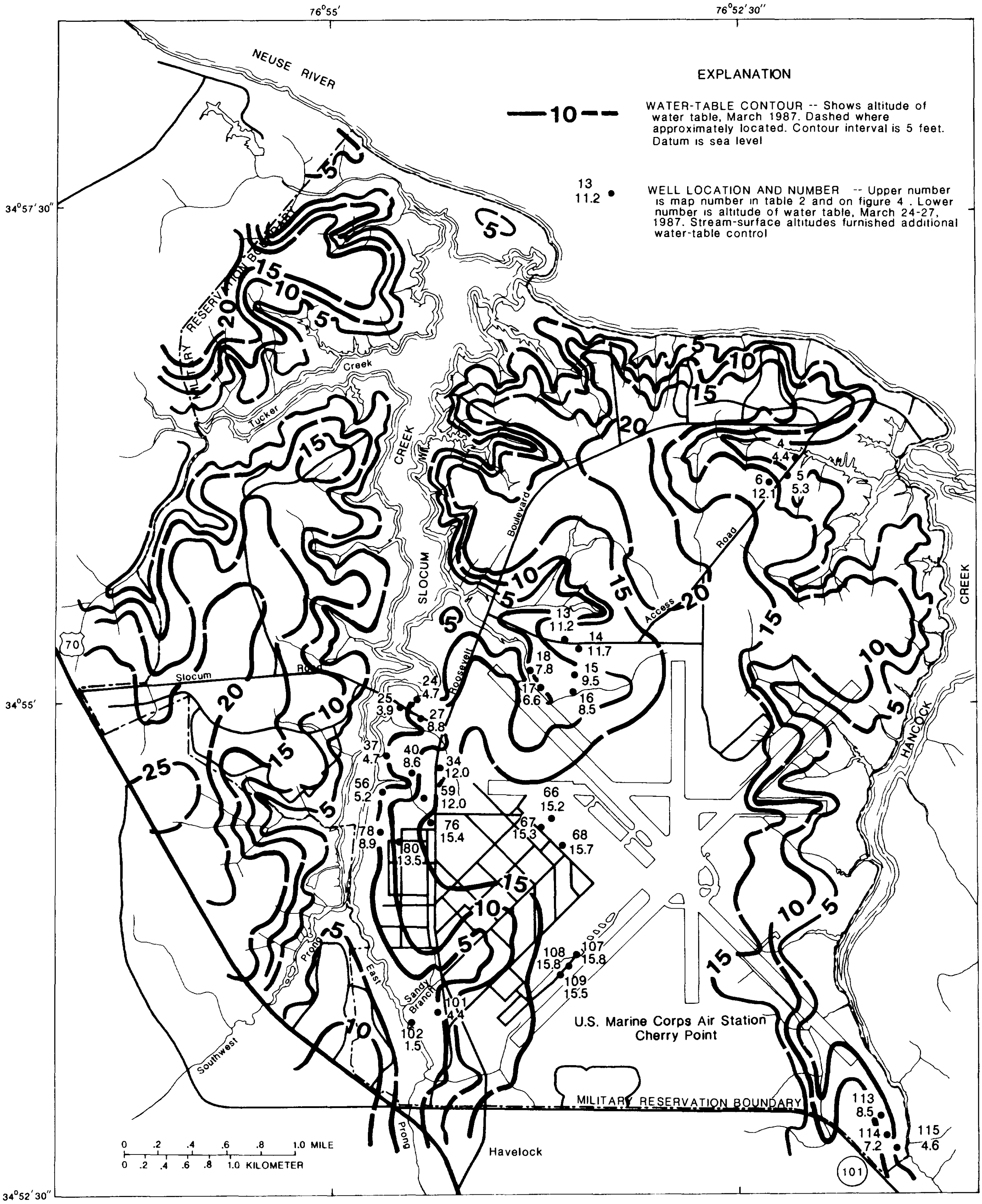

Figure 7.--Approximate altitude of the water table, U.S. Marine Corps Air Station, Cherry Point, North Carolina.

the surficial and Yorktown aquifers and the Castle Hayne aquifer at waste-disposal site 10.

Map well number (fig. 4 and table 2)	Well depth below land surface (feet)	Hydrologic unit	Water level[a] above or below (-) sea level (feet)
41	19.7	Surficial and Yorktown aquifers	8.35
47	70	Pungo River aquifer	6.06
33[b]	195	Castle Hayne aquifer	-8.6[c]

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[a] Water-level measurements made between March 24 and 27, 1987.
[b] Well located about 0.2 mi from wells 41 and 47.
[c] Pumping water level; a nonpumping water level in the Castle Hayne aquifer near wells 41 and 47 is about 3.0 ft above sea level (extrapolated from figure 9).

Because there are few, if any, active production wells in the Pungo River aquifer and because contaminated water is found in some supply wells tapping the Castle Hayne aquifer (see quality of water section of this report), it is assumed, under present hydrologic conditions, that water levels in this aquifer are intermediate between those in the shallow and deep aquifers throughout most of the Air Station. Thus, it is further assumed that ground water has the potential to move vertically downward from the surficial and Yorktown aquifers through the Pungo River aquifer and into the Castle Hayne aquifer throughout most of the area. These assumptions will be tested when more hydraulic-head data are collected for the Pungo River aquifer.

Castle Hayne Aquifer

The Castle Hayne aquifer provides water for domestic, municipal, and industrial users throughout eastern North Carolina. As wells were drilled and the number and amount of ground-water withdrawals grew, the potentiometric surface of the Castle Hayne aquifer has been lowered around the centers of pumping. The Air Station is but one of the many users that has caused water-level declines in the Castle Hayne aquifer.

Figure 8 shows the approximate altitude of the potentiometric surface of the Castle Hayne aquifer at the Air Station in the fall of 1941. The map was constructed from historical data on reported nonpumping water levels that were obtained from the U.S. Marine Corps files at the Air Station. It appears that the altitude of the potentiometric surface ranged from about 14 ft above sea level in the southern part of the Air Station to about 6 ft above sea level near the northern tip of the peninsula. Thus, water was moving from southwest to northeast within the Castle Hayne aquifer beneath the study area at that time.

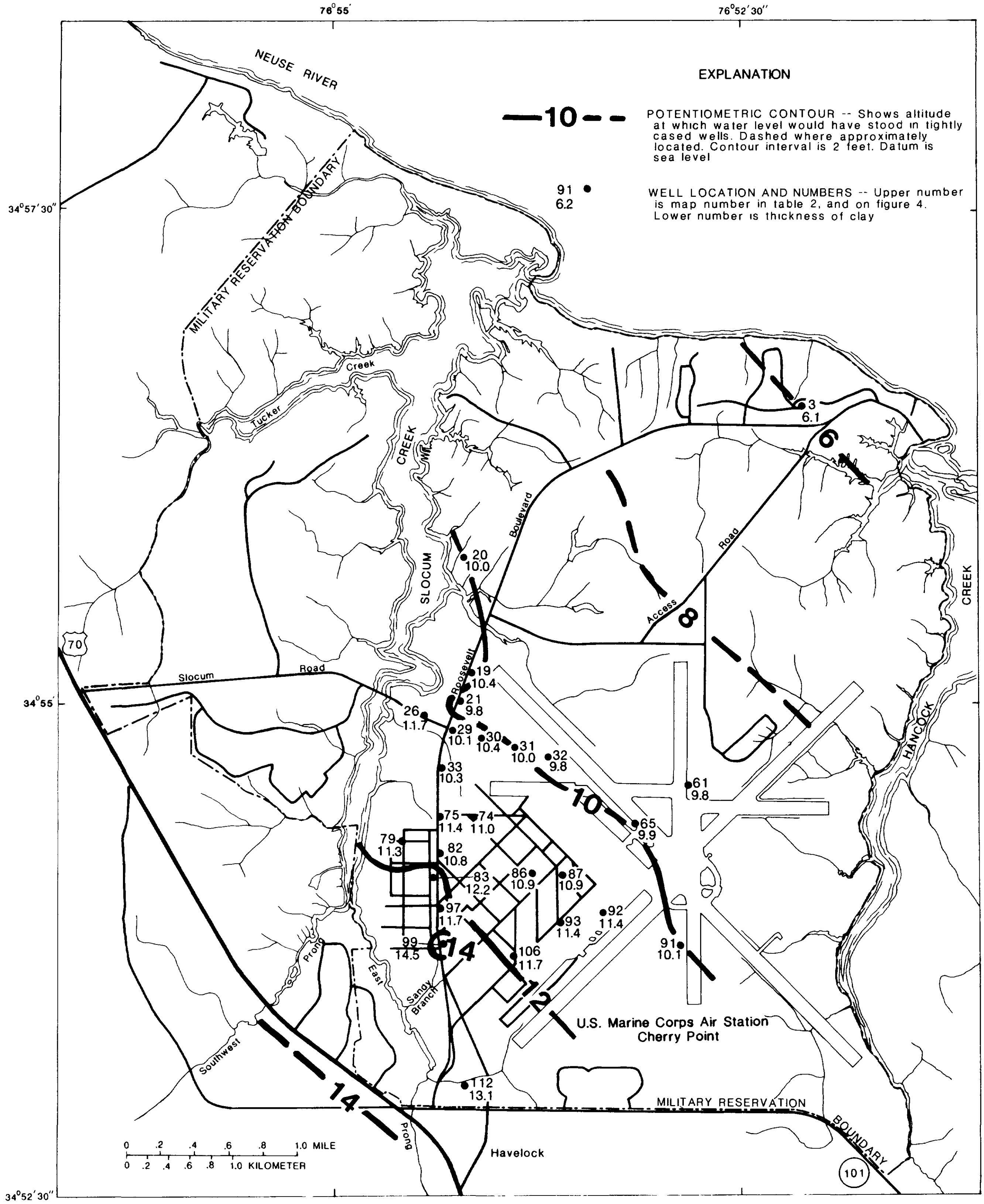


Figure 8.--Approximate altitude of the potentiometric surface of the Castle Hayne aquifer, fall 1941, U.S. Marine Corps Air Station, Cherry Point, North Carolina.

For comparison purposes, it is assumed that the water table away from the central part of the peninsula, as measured in 1987, is about the same as that in 1941. A comparison of figures 7 and 8 can be used to estimate the direction of vertical ground-water flow that took place in 1941 in areas other than the central part of the peninsula. This comparison suggests that the potentiometric surface of the Castle Hayne aquifer was higher than the water table in an area extending about 0.5 mi on either side of Slocum Creek and the west side of Hancock Creek. The head difference could have been as much as 7 ft in the southern part of the area along parts of Sandy Branch and East Prong. Thus, is it estimated that in the fall of 1941, water was moving upward from the Castle Hayne into the shallow aquifers in much of the Sandy Branch drainage area and beneath many of the hazardous-waste disposal and spill sites shown located near the major streams on figure 2.

The approximate altitude of the potentiometric surface in the Castle Hayne aquifer in March 1987 is shown in figure 9. The map was constructed from water-level measurements made during March 24-27, 1987, in 22 wells tapping the Castle Hayne aquifer. Water-level measurements were made in both pumping and nonpumping wells. The altitude of the water levels in the Castle Hayne aquifer range from about 7 ft above sea level in Well 9 (MCAS Well 21) to as much as about 20 ft below sea level in Well 12 (MCAS Well 24).

A comparison of figures 8 and 9 indicates that there has been a general lowering of the potentiometric surface in the Castle Hayne aquifer caused by pumping water from the supply wells from 1941 to present. It is assumed that the details of the cones of depression around the wells change as different groups of wells are pumped. Maximum water-level declines are estimated to be about 30 ft around some of the pumping wells. Declines in the potentiometric surface in nonpumping areas range from about 10 ft in the southern part of the area to about 2 ft near the northern tip of the peninsula. Figure 9 indicates that ground water within the Castle Hayne aquifer beneath most of the Air Station is now moving toward the pumping supply wells. A comparison of figures 7 and 9 suggests that ground water now has the potential to move downward from the shallower aquifers into the Castle Hayne aquifer throughout most of the Air Station.

A small part of the decline of the potentiometric surface in the Castle Hayne aquifer may be caused by the interference or overlapping of the cones of depression around the municipal wells at the Town of Havelock (pumping about 0.75 Mgal/d) and, possibly, from the very large withdrawals (65 Mgal/d) at the phosphate mines in Beaufort County about 30 mi north of the Air Station. The water-level decline near the center of pumping for the phosphate mines in Beaufort County is about 150 ft compared to about 30 ft for some of the pumping wells at the Air Station.

Even though a long-term decline in the potentiometric surface of the Castle Hayne aquifer is indicated by the comparison of figures 8 and 9, this decline has not been uniform over time but has been subject to short-term fluctuations resulting mainly from irregular pumping cycles and seasonal climatic effects. For example, figure 10 shows a graph of water levels in Well 26 (MCAS Well 20) from August 1986 to February 1987. The steep rises and declines that occur over time periods of a week (more or less) on the graph are water-level fluctuations caused by the pumping of nearby supply wells. The more long-term decline and rise of water levels are seasonal fluctuations.

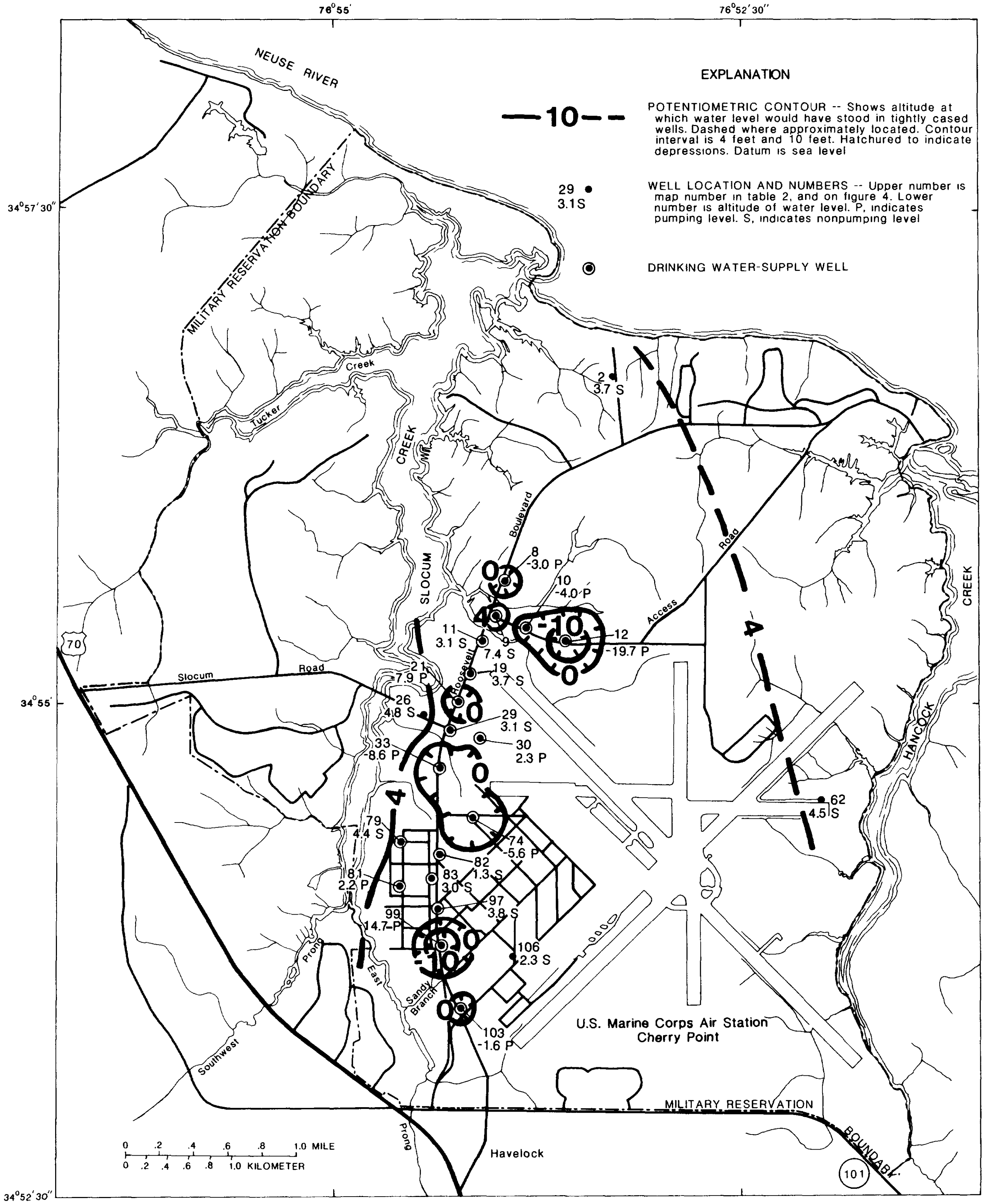
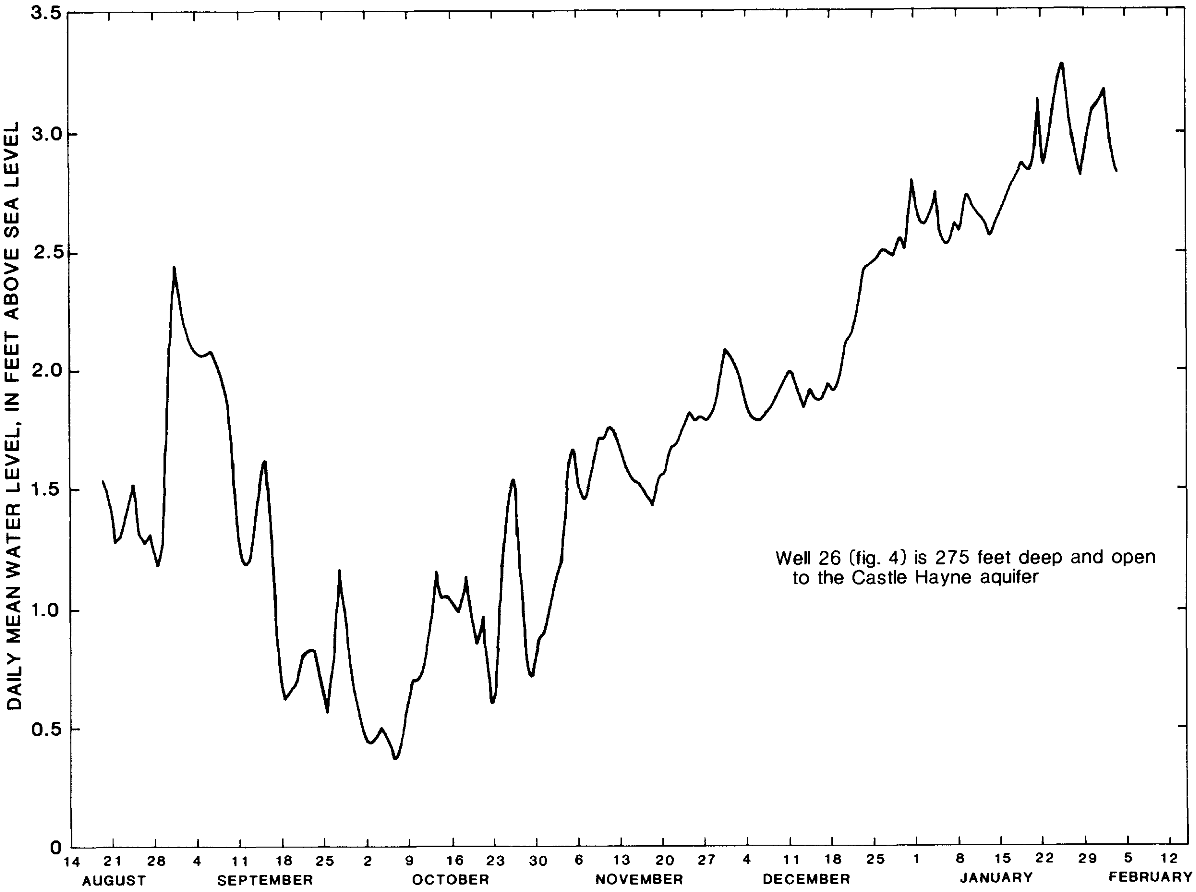


Figure 9.--Approximate altitude of the potentiometric surface in the Castle Hayne aquifer, March 24-27, 1987, U.S. Marine Corps Air Station, Cherry Point, North Carolina.



Well 26 (fig. 4) is 275 feet deep and open to the Castle Hayne aquifer

Figure 10.--Hydrograph of Well 26 (MCAS Well 20), from August 1986 to February 1987, U.S. Marine Corps Air Station, Cherry Point, North Carolina.

The seasonal water-level declines are caused by discharge, both natural and from pumpage, exceeding recharge to the aquifer, and the water-level rises are caused by recharge exceeding discharge. Discharge from the ground-water system generally exceeds recharge during the growing season when high rates of evapotranspiration occur. Conversely, recharge to the system generally exceeds discharge during the nongrowing season when evapotranspiration rates are low. Some of the water-level rise during the nongrowing season may be caused by a decrease in the amount of pumpage from the aquifer.

QUALITY OF WATER FROM SUPPLY WELLS

Because at least one of the waste-disposal and spill sites will be regulated under provisions of the Resource Conservation and Recovery Act (RCRA), the potential legal ramifications of this study dictated that the utmost care be exercised during sample collection and analysis to ensure the validity and accuracy of results. It is also important that others who will use the results of this work be able to evaluate the procedures used during sample collection and analysis. This is especially important when making comparisons between this study and previous studies and perhaps some future study as well. Sampling methodology and analytical procedures tend to evolve over time as knowledge and technology evolve. Certainly the detection limits for substances being analyzed are becoming smaller and smaller as analytical procedures and equipment become even more sophisticated. Thus, it is unlikely that procedures used during this study will exactly duplicate the procedures employed in previous studies, nor is it likely that they will be duplicated in future studies. If there are differences between the results of these studies, it is important to be able to compare sampling and analytical procedures to determine whether the differences are the result of real changes in the hydrogeologic system being studied or perhaps the result of differences in which the data were obtained.

Consequently, the next two sections of this report, sample collection and sample analysis, describe in considerable detail the manner in which samples were collected and handled, the equipment used, precautions taken against contamination of samples, and shipping of samples. A brief description is also given of field measurements of selected water-quality parameters and a quality-assurance program of duplicate samples and shipment blanks that were sent along with the samples to the laboratories for analysis. The addresses of the two laboratories that performed the analytical work for this study are included for the reader who may wish more information on laboratory procedures.

Sample Collection

Between October 7 and November 7, 1986, water samples were collected from 21 water-supply wells on the Marine Corps Air Station at Cherry Point, North Carolina, and submitted to laboratories for chemical analysis. The sampled wells include 19 wells that provide potable water for the Air Station. One well (Well 2, fig. 4, table 2) is an irrigation-supply well that provides water for the golf course sprinkler system; another (Well 106, fig. 4, table 2) is an industrial-supply well at the Naval Aircraft Rework Facility (NARF).

Because ground-water contamination is an issue of considerable concern, special sampling and handling procedures were developed. Special consideration was given to a number of items, including: clothing worn by personnel collecting and handling samples, equipment used to collect the samples, cleaning of sampling equipment, special containers for the samples, methods of sample collection, and a quality assurance-quality control (QA-QC) program.

Special protective clothing worn by personnel collecting and handling samples and sampling equipment included Tyvek[2] coveralls, a combination of latex and nitrile gloves, glasses or goggles, and hardhats. Although the clothing was worn as part of a program of personal safety, a primary purpose of the special clothing was to prevent possible contamination of the samples by dust, dirt, oils, sweat, and others substances that might come from the clothing and bodies of the people collecting the samples. This was a constant concern because of the low detection limits (table 3) and sensitivity of the analytical procedures that were used.

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[2] Use of brand/firm/trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Samples were collected with special fixed-interval samplers, or bailers, constructed of Teflon that had check valves at both ends. The bailer had an inside diameter of 1.5 in., was 4 ft in length, and could hold about 0.75 L of sample.

All equipment used for sampling or that would come in contact with sampling equipment was cleaned in a multi-step cleaning procedure. Cleaning was accomplished in several steps, as listed below:

1. Disassemble any equipment that can be taken apart (this applies primarily to the bailers).
2. Wash and scrub equipment with tap water and a nonphosphate detergent (Alconox) designed for cleaning laboratory equipment and glassware.
3. Rinse with tap water.
4. Rinse with pesticide-grade acetone (Fisher Scientific no. A40-4) UN no. UN1090.
5. Rinse with pesticide-grade methanol (Fisher Scientific no. A450-4) UN no. UN1230.
6. Rinse with deionized water.
7. Air dry.
8. Wrap in heavy-duty aluminum foil, dull side toward equipment.

All equipment was washed at least one day prior to use to ensure that all cleaning agents would have time to evaporate. Only one well a day was sampled, and the equipment was cleaned between each sampling to avoid the possibility of cross-contamination of samples. Equipment that was cleaned each day in preparation for the next sampling included the bailer(s), a stainless-steel sounding weight used to determine the bottom of the well, stainless-steel pans and trays in which other clean equipment could be placed, and gloves to be worn during sampling.

All sample containers were obtained from the Survey laboratory in Arvada, Colorado. Depending upon the type of analysis to be run, samples were placed in containers, either glass or plastic, as specified for a particular analysis. In general, the samples for organic analysis were placed in glass containers and samples for major cations, anions, and metals were placed in plastic containers. Glass containers for samples to be analyzed for organic compounds on the U.S. Environmental Protection Agency priority pollutant list had been baked at 300 °C to ensure removal of possible contaminants. The lids to these containers were either teflon lined or had a teflon septum, as in the case of the vials for purgeable organics samples to prevent possible contamination from the plastic lid. The types of sample containers, method of preservation, and quantities of samples required for particular analyses are described in detail by Feltz and Anthony (1984).

A standardized sampling procedure was developed to ensure day-to-day consistency in the collection of samples, field measurements, sample preparation and preservation, and shipping to the laboratory. All wells except Well 9 (MCAS Well 21) were pumped for at least an hour at a rate of about 200 gallons per minute prior to pump removal and sampling. Most wells were pumped for much longer periods; some had been running continuously prior to sampling. The purpose of the pumping was to ensure that fresh formation water was present opposite the open-hole or screened interval near the bottom of the well at the time of sampling. Well 9 was inadvertently taken out of service about three days before it was sampled.

On the morning that a well was to be sampled, the pump was turned off, electrical wiring and pipes disconnected from the pump head, and the entire pump assembly removed from the well with a crane. As the pump column was removed, it was inspected for corrosion and leaks, particularly at couplings. Any necessary repairs were made prior to resetting the pump into the well. To ensure the safety of personnel working in the well house, the pump assembly was lifted clear of the well house and swung to one side of the building where it remained suspended until sampling was completed or repairs made.

A major reason for removing the pumps from the wells and utilizing a fixed interval sampler to collect samples from the producing zone at the bottom of the wells was to minimize the loss of dissolved gases and volatile organic compounds that would occur if samples were collected from the discharge line coming from the pump. The loss of volatiles that could occur due to the drop in pressure, cavitation, turbulence, and aeration as the water was pumped from the well and discharged to the atmosphere had to be avoided. A fixed interval sampler allowed a sample to be collected from the aquifer under ambient conditions of temperature and pressure and with a minimum of turbulence and aeration. Another reason for removing the pumps was to allow access for geophysical logging. The disadvantage of removing the pumps was that it made the water turbid as it occasionally scraped the sides of the well casing and dislodged sediment and incrustation that might be on the well casing and (or) pump column.

As soon as the pump was removed, the pump pier and adjacent parts of the well-house floor were covered with polyethylene plastic to cover loose dirt, rust, and water and help ensure a clean work environment. A hole was cut in the plastic at the top of the pump pier to allow access into the well. Next, a tripod was set up and centered over the well casing. At this point, the two people who would do the sampling put on coveralls and gloves and proceeded to sound the well with a precleaned, stainless-steel weight suspended on a new nylon line. Care was taken to prevent the nylon line from coming into contact with the floor or plastic sheeting. A large stainless-steel tray was placed beside the tripod to catch the nylon line as it was pulled out of the well. Once the weight was lowered to the bottom of the well, the weight was pulled back about 6 ft and the nylon line marked at the top of the well casing. This mark served to establish the fixed interval to be sampled in the screened or open-hole section at the bottom of the well. The sounding weight was then retrieved and a bailer attached to the nylon line. At this point, sampling could begin.

As the bailer was lowered into a well, the check valves remained open and water flowed through the sampler until it came to rest. Once the sampler was no longer being lowered, the check valves closed and a sample of water from the depth at which the sampler stopped its descent was captured in the bailer and then brought to the surface. Upon arrival at the surface, the sample was transferred into sample containers by means of a special teflon nozzle that was inserted into the sampler and released the check valve.

After sufficient sample was recovered from a well, the tripod and bailer were removed from the well house. The person who had been bailing would then assist with the geophysical logging of the well. Sample preparation, filtering, preservation, and labeling were completed in a mobile field laboratory out of the way of the logging operation.

Some samples were filtered for later determination of dissolved constituents. Sufficient water for the filtered samples was removed from the well and temporarily stored in baked glass liter jars with teflon lids and kept on ice. Additional water was collected for field determinations of dissolved oxygen (made immediately upon collection at the well head), pH, conductivity, and alkalinity (made shortly after collection at the mobile lab).

During sampling, sample bottles were arranged in stainless-steel or aluminum trays to further reduce the risk of sample contamination. An additional precaution was the rinsing out of sample bottles with sample water, which was then discarded, prior to finally filling the sample bottle. This was done for both the filtered and unfiltered samples.

Except during the brief intervals when a sample was being handled, filtered, or labeled, samples were kept on ice in a cooler which also served as a shipping container. Samples collected on Monday through Thursday were delivered to the Havelock, N.C., post office on the afternoon of the day collected and sent by overnight express mail to the two laboratories that would analyze the samples. Samples collected on Fridays were transferred to the Survey headquarters in Raleigh, N.C., where they were kept refrigerated over the weekend and then sent out by express mail the following Monday. The Friday samples were handled this way to eliminate the possibility that the ice in the coolers could melt and the samples become warm over the weekend.

Sample Analysis

As mentioned in the previous section, samples were shipped to two separate laboratories. In general, samples for the determination of major cations and anions, physical properties and characteristics, nutrients, metals, other selected constituents, and purgeable (volatile) organic compounds were sent to the U.S. Geological Survey, Branch of Analytical Services, Water Quality Laboratory, 5293 Ward Road-B, Arvada, Colorado 80002. Samples for the determination of acid extractable and base/neutral extractable organic compounds, organochlorine and organophosphorus pesticides, and PCB's (polychlorinated biphenyls) were sent to the Tennessee Valley Authority, Laboratory Branch, 150 401 Building, Chattanooga, Tennessee 37401.

Analyses for major cations and anions, physical properties and characteristics, nutrients (except dissolved organic carbon), metals, and other selected constituents (except methylene blue active substance) were made in accordance with standardized U.S. Geological Survey procedures for inorganic substances as described by Fishman and Friedman (1985). Analyses for dissolved organic carbon, methylene blue active substance, and purgeable (volatile) organic compounds were made in accordance with standardized U.S. Geological Survey procedures for organic substances as described by Wershaw and others (1983). The procedures for purgeable organic compounds described by Wershaw and others (1983) incorporate the procedures of U.S. Environmental Protection Agency (EPA) Method 624 as described in the Federal Register (U.S. Environmental Protection Agency, 1984a).

Analytical procedures used by the Tennessee Valley Authority for the analysis of acid extractable and base/neutral extractable organic compounds, organochlorine and organophosphorus pesticides, and PCB's incorporated the U.S. Geological Survey procedures and guidelines as described by Wershaw and others (1983). The procedures for acid extractable and base/neutral extractable compounds described by Wershaw and others (1983) incorporate the procedures of U.S. Environmental Protection Agency Method 625 as described in the Federal Register (U.S. Environmental Protection Agency, 1984b).

Quality control procedures used by the laboratories to ensure the accuracy of analytical results are described by Wershaw and others (1983) and Fishman and Friedman (1985). Field procedures were also implemented to ensure the integrity of the samples during sampling, handling, and shipping. The field sampling procedures and equipment preparation are described in the previous section. To reduce the possibility of erroneous results from improperly cleaned or contaminated sample containers, all sample containers were new and specially cleaned either by the U.S. Geological Survey Laboratory or the container manufacturer for specific analytical procedures. All sample containers were also field rinsed with sample water as an added precaution before being filled and sealed for shipment. To monitor the possibility of contamination that might be introduced by or during sampling and shipment, shipment blanks (empty sample containers) were occasionally included in the sampling process and shipped along with the samples to the laboratory. At the lab, these bottles were rinsed out with distilled water and the rinse water was then analyzed. Results of analyses on these shipment blanks were negative.

Results of the requested analyses for organic and inorganic substances and physical properties and characteristics of water samples from supply wells at the Air Station are presented in table 3 in the basic data section at the back of this report. Included in table 3 are all but seven of the substances listed in the EPA list of priority pollutants (table 4). The seven substances for which analyses were not performed are: acrolein, acrylonitrile; bis (chloromethyl) ether; 2,4-dimethylphenol; 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD); thallium; and asbestos (fibrous).

These substances were not run because of the extreme toxicity of the substance which precluded having analytical standards (for example 2,3,7,8-tetrachlorodibenzo-p-dioxin), instability of the standards, or other reasons. In the case of fibrous asbestos, the hazard is primarily from inhalation into the lungs and not from ingestion in drinking water. In the case of 2,4-dimethylphenol, the absence of an analysis for this compound is probably a moot point because the analyses for total phenols, which were run on samples from all wells, gave results less than the detection limit of 5 µg/L.

Library searches were run on unidentified organic substances detected during analyses for acid extractable, base/neutral extractable, and purgeable organic compounds. These library searches were made using spectral data available for nearly 39,000 known organic compounds. These libraries are maintained by the National Bureau of Standards (NBS) and by the Environmental Protection Agency--National Institute of Health (EPA-NIH). The library search for purgeable organic compounds conducted by the U.S. Geological Survey laboratory used the NBS library, and the search to identify acid extractable and base/neutral extractable compounds conducted by the Tennessee Valley Authority laboratory used the EPA-NIH library. The results of the searches and the compounds tentatively identified are not given in table 3 but are presented and discussed in a later section of this report.

Table 4.--U.S. Environmental Protection Agency list of priority pollutants

[The 129 substances listed in the table below were compiled from U.S. Environmental Protection Agency (1979a, 1979b).]

PURGEABLE ORGANICS

- Acrolein*
- Acrylonitrile*
- Benzene
- Toluene
- Ethylbenzene
- Carbon tetrachloride
- Chlorobenzene
- 1,2-Dichloroethane
- 1,1,1-Trichloroethane
- 1,1-Dichloroethane
- 1,1-Dichloroethylene
- 1,1,2-Trichloroethane
- 1,1,2,2-Tetrachloroethane
- Chloroethane
- 2-Chloroethyl vinyl ether
- Chloroform
- 1,2-Dichloropropane
- 1,3-Dichloropropene
- Methylene chloride
- Methyl chloride
- Methyl bromide
- Bromoform
- Dichlorobromomethane
- Trichlorofluoromethane
- Dichlorodifluoromethane
- Chlorodibromomethane
- Tetrachloroethylene
- Trichloroethylene
- Vinyl chloride
- 1,2-trans-Dichloroethylene
- bis(Chloromethyl) ether*

BASE/NEUTRAL EXTRACTABLE ORGANICS

- 1,2-Dichlorobenzene
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- Hexachloroethane
- Hexachlorobutadiene
- Hexachlorobenzene
- 1,2,4-Trichlorobenzene
- bis(2-Chloroethoxy) methane
- Naphthalene
- 2-Chloronaphthalene
- Isophorone
- Nitrobenzene
- 2,4-Dinitrotoluene
- 2,6-Dinitrotoluene
- 4-Bromophenyl phenyl ether
- bis(2-Ethylhexyl)phthalate
- Di-n-octyl phthalate
- Dimethyl phthalate
- Diethyl phthalate
- Di-n-butyl phthalate
- Acenaphthylene
- Acenaphthene
- Butyl benzyl phthalate
- Fluorene
- Fluoranthene
- Chrysene
- Pyrene
- Phenanthrene
- Anthracene
- Benzo(a)anthracene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Indeno(1,2,3-c,d)pyrene
- Dibenzo(a,h)anthracene
- Benzo(g,h,i)perylene
- 4-Chlorophenyl phenyl ether
- 3,3'-Dichlorobenzidine
- Benzidine
- bis(2-Chloroethyl) ether
- 1,2-Diphenylhydrazine
- Hexachlorocyclopentadiene
- N-Nitrosodiphenylamine
- N-Nitrosodimethylamine
- N-Nitrosodi-n-propylamine
- bis(2-Chloroisopropyl) ether

ACID EXTRACTABLE ORGANICS

- Phenol
- 2-Nitrophenol
- 4-Nitrophenol
- 2,4-Dinitrophenol
- 4,6-Dinitro-o-cresol
- Pentachlorophenol
- p-Chloro-m-cresol
- 2-Chlorophenol
- 2,4-Dichlorophenol
- 2,4,6-Trichlorophenol
- 2,4-Dimethylphenol*

PESTICIDES/PCB'S

- α-Endosulfan
- β-Endosulfan
- Endosulfan sulfate
- α-BHC
- β-BHC
- δ-BHC
- γ-BHC (Lindane)
- Aldrin
- Dieldrin
- 4,4'-DDE
- 4,4'-DDD
- 4,4'-DDT
- Endrin
- Endrin aldehyde
- Heptachlor
- Heptachlor epoxide
- Chlordane
- Toxaphene
- Aroclor 1016
- Aroclor 1221
- Aroclor 1232
- Aroclor 1242
- Aroclor 1248
- Aroclor 1254
- Aroclor 1260
- 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)*

METALS AND OTHER INORGANIC ELEMENTS

- Antimony
- Arsenic
- Beryllium
- Cadmium
- Chromium
- Copper
- Lead
- Mercury
- Nickel
- Selenium
- Silver
- Thallium*
- Zinc

MISCELLANEOUS

- Asbestos (fibrous)*
- Total cyanides
- Total phenols

*Substances for which analyses were not made during this study.

Inorganic Constituents

A statistical summary for water-quality characteristics of water from 21 supply wells completed in the Castle Hayne aquifer at the Air Station is shown in table 5. This table is a synthesis of the inorganic constituents and other water-quality parameters listed in table 3. For those constituents for which some concentrations are reported as less than detection limit in table 3, a concentration value of half the difference between the detection limit and zero was arbitrarily chosen and used to determine the median, mean, and standard deviation statistics shown in table 5. Where all concentrations are less than detection limits, no statistics are reported.

Major Cations and Anions

The concentrations of the major cations and anions in water from the supply wells indicate the water is a calcium-bicarbonate type that contains moderate amounts of dissolved silica. The equivalent proportions of the major cations and anions is fairly constant in the samples from all the wells except Wells 19 (MCAS Well 6) and 74 (MCAS Well 9). This fact is well illustrated on the trilinear plot shown in figure 11. Water from Well 19 (MCAS Well 6) and Well 74 (MCAS Well 9) has lower percentage concentrations of calcium and higher percentage concentrations of sodium and chloride than water from the other wells. Because these two wells are the deepest of all those sampled, it is believed that the higher concentrations of sodium and chloride are a result of water sampled from deeper parts of the aquifer which contains greater proportions of saltwater.

The following table suggests that there may have been a progressive increase of chloride concentrations in water from Well 19 (USMC Well 6) from 1942 to 1986. Even though the present concentrations are more than five times less than the drinking-water standard (U.S. Environmental Protection Agency, 1986), the four-fold increase in chloride may be evidence of the first signs of saltwater encroachment at this well.

Date of sample collection	Chloride concentrations in water from Well 19 (USMC Well 6) (mg/L)
2/28/42	10
5/27/59	37
10/15/86	43

Nutrients

The concentration of dissolved organic carbon (DOC) in water from the supply wells is noteworthy. The median DOC concentration of 7.4 mg/L is about 10 times higher than that for water from most limestones throughout the United States (Leenheer and others, 1974). However, the small range (table 5) of the DOC concentrations in water from the supply wells suggests that this may be a regional characteristic of the water in the Castle Hayne aquifer and might not be caused by contamination from the hazardous-waste and spill sites at land surface. Indeed, Thurman (1985, p. 14) reports that it is not unusual for ground waters, where recharged by organic rich surface water in the southeastern part of the United States, to contain concentrations of DOC that range from 6 to 15 mg/L. Additional sampling and analysis will be needed to determine the source of the DOC in water from the supply wells.

Table 5.--Selected statistics for water-quality characteristics of water from wells in the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina

[mg/L, milligrams per liter; µg/L, micrograms per liter; cm, centimeter]

Parameter	Number of samples	Range	Median	Mean	Standard deviation
Major Cations					
Calcium, dissolved (mg/L as Ca)	21	60-89	78	79	6
Magnesium, dissolved (mg/L as Mg)	21	1.8-4.0	2.8	2.9	.6
Potassium, dissolved (mg/L as K)	21	2.0-7.4	4.3	4.5	1.3
Silica, dissolved (mg/L as SiO_2)	21	26-36	33	33	2.2
Sodium, dissolved (mg/L as Na)	21	6.7-64	12.0	17.0	15.2
Major Anions					
Bicarbonate, total, field (mg/L as HCO_3)	21	270-390	330	328	38
Chloride, dissolved (mg/L as CL)	21	6.9-43	8	10.4	7.7
Sulfate, dissolved (mg/L as SO_4)	21	3.6-8.0	6.0	6.0	1.2
Physical Properties and Characteristics					
Alkalinity, total, field (mg/L as $CaCO_3$)	21	225-321	268	268	30
Alkalinity by titration to pH 4.5, lab (mg/L as $CaCO_3$)	21	185-271	223	226	18
Color (Platinum-cobalt units)	21	5-60	35	33	15
Hardness, total (mg/L as $CaCO_3$)	21	170-230	210	209	14
pH, field	21	6.68-7.50	7.25	--	--
Specific conductance, field (microsiemens/cm)	21	400-657	437	449	58
Specific conductance, lab (microsiemens/cm)	21	402-613	439	449	46
Temperature, field (degrees Celsius)	21	18-21.5	19.0	19.2	1.0
Turbidity (nephelometric turbidity units)	21	3.8-300	32	57.2	69.8

Table 5.--Selected statistics for water-quality characteristics of water from wells in the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina--Continued

Parameter	Number of samples	Range	Median	Mean	Standard deviation
		Nutrients			
Ammonia nitrogen, dissolved (mg/L as N)	21	.23-.56	.40	.40	.10
Ammonia plus organic nitrogen, dissolved (mg/L as N)	21	0.4-2.4	0.8	1.0	.5
Nitrate nitrogen, dissolved (mg/L as N)	7	.008-.037	--	--	--
Nitrite nitrogen, dissolved (mg/L as N)	21	.0005-.005	.002	.002	.002
Nitrite plus nitrate nitrogen, dissolved (mg/L as N)	21	.005-.040	.005	.012	.012
Organic carbon, dissolved (mg/L as C)	21	5.2-8.2	7.4	7.2	.8
Phosphorous, ortho, dissolved (mg/L as P)	21	.001-.021	.006	.008	.005
		Metals			
Cadmium, total (µg/L as Cd)	21	.5-3	.5	.7	.6
Chromium, total (µg/L as Cr)	21	.5-26	3	6.6	7.8
Copper, dissolved (µg/L as Cu)	21	.5-5	2	1.9	1.1
Copper, total (µg/L as Cu)	21	4-120	29	35	29
Iron, dissolved (µg/L as Fe)	21	58-1,600	780	728	453
Lead, total (µg/L as Pb)	21	2.5-400	7	29	86
Manganese, dissolved (µg/L as Mn)	21	28-260	79	102	60
Mercury, total (µg/L as Hg)	21	All samples less than detection limit (<0.1)			
Nickel, total (µg/L as Ni)	21	.5-400	3	24	87
Silver, total (µg/L as Ag)	21	.5-4	.5	.8	.8
Zinc, total (µg/L as Zn)	21	20-1,800	110	244	425

Table 5.--Selected statistics for water-quality characteristics of water from wells in the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina--Continued

Parameter	Number of samples	Range	Median	Mean	Standard deviation
	Other Constituents				
Antimony, total (µg/L as Sb)	21	.5-2	.5	.6	.3
Arsenic, total (µg/L as As)	21	.5-14	.5	1.6	3.0
Beryllium, total (µg/L as Be)	21	5-10	5	5.2	1.1
Boron, dissolved (µg/L as B)	21	20-120	30	38	28
Carbon dioxide, dissolved (mg/L as CO_2)	20	18-130	28	34	25
Cyanide, total (mg/L as CN)	21	All samples less than detection limit (<0.01)			
Dissolved oxygen (mg/L as O_2)	21	.8-3.3	1.5	1.7	.7
Dissolved solids, sum of constituents (mg/L)	21	270-390	290	306	35
Dissolved solids residue at 180° C (mg/L)	21	272-473	300	315	45
Fluoride, dissolved (mg/L as F)	21	.2-.5	.2	.25	.1
Methylene blue active substance (mg/L as MBAS)	21	.02-.05	.04	.04	.02
Selenium, total (µg/L as Se)	21	All samples less than detection limit (<1)			

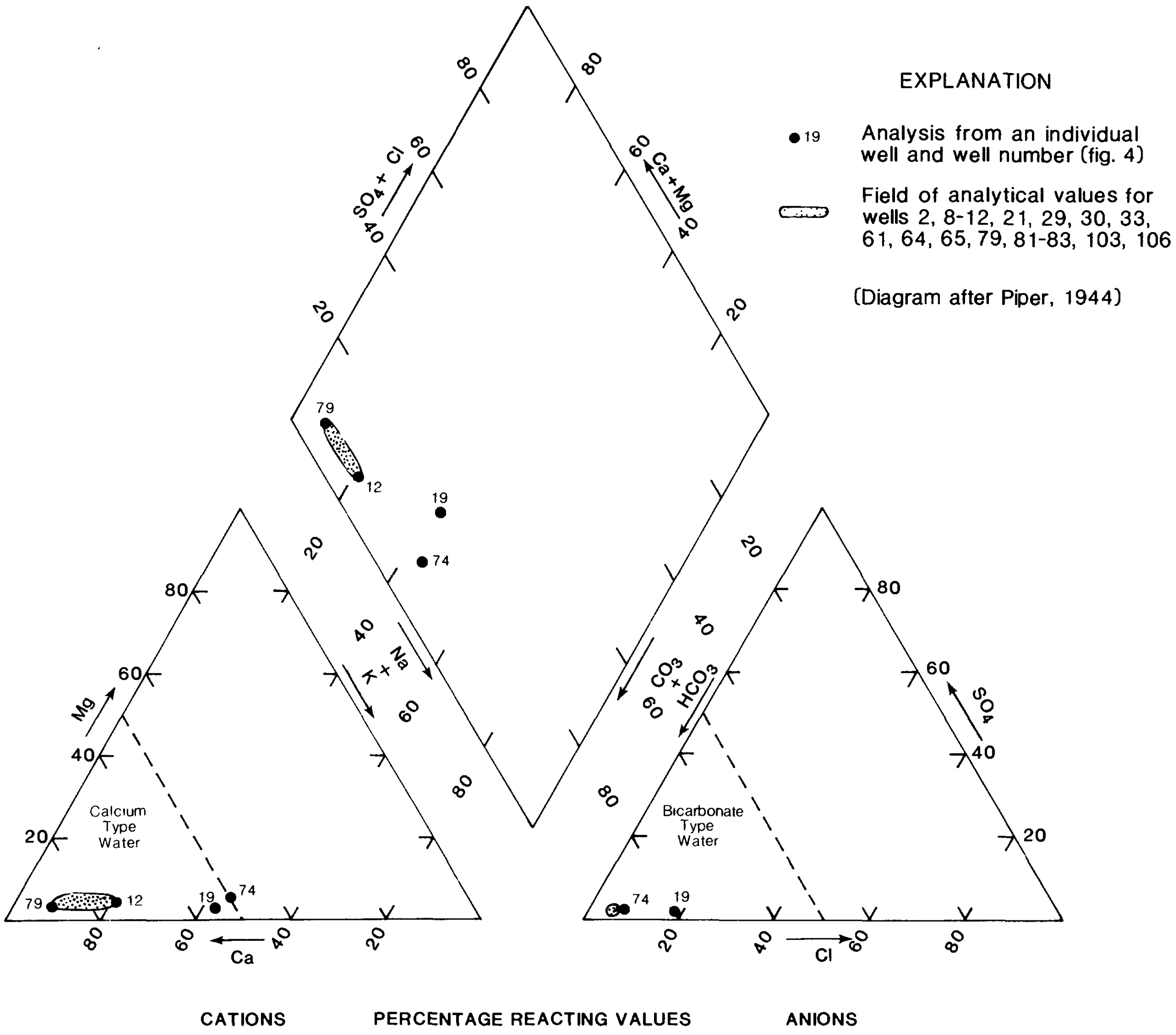

Figure 11.--Trilinear diagram of major cations and anions in water from wells in the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina.

Metals

Of all the metals for which analyses were made (table 5), only iron, manganese, lead, and nickel exceeded standards listed in the EPA ambient water-quality criteria (U.S. Environmental Protection Agency, 1986). The concentrations of dissolved iron and manganese were found to exceed maximum amounts (0.3 and 0.05 mg/L, respectively) recommended for secondary drinking-water standards in two-thirds of the raw water samples.

Concentrations of total lead and nickel were very near or above the ambient water-quality criteria, 50 µg/L for lead and 13.4 µg/L for nickel, (table 3) in water from three wells. Figure 12 shows concentrations of lead were 55 µg/L in water from Well 79 (MCAS Well 13) and 400 µg/L in water from Well 12 (MCAS Well 25). Figure 13 shows concentrations of nickel were 13 µg/L in water from Well 79 (MCAS Well 13), 48 µg/L in water from Well 81 (MCAS Well 19), and 400 µg/L in water from Well 12 (MCAS Well 25).

If it is assumed that all wells are yielding approximately the same amount of water to the water lines, and that all wells with concentrations of lead and nickel higher than detection limits (<5 and <1 µg/L, respectively), as shown on figures 12 and 13, are contributing to the water lines, then it can be estimated that it would take a minimum of 12 pumping wells to dilute the lead concentrations to below the EPA ambient water-quality criteria (50 µg/L), and a minimum of 39 pumping wells to dilute the nickel to below the quality criteria (13.4 µg/L). The number of pumping wells needed to dilute the lead is reasonable, but the number needed to reduce the nickel is unrealistic because only about 20 wells exist at present. However, if Well 12 (MCAS Well 25), which produced water with 400 µg/L of both lead and nickel, is eliminated from contributing water to the lines, the number of pumping wells needed to dilute the lead and nickel to acceptable concentrations is 4 and 9, respectively.

The unusually high concentrations of these metals may have been introduced from hazardous-waste disposal or spill sites at land surface, or it is possible that these metals may have come from clay and metal particles that were dislodged by the bailer from the rock in the open hole part of the well, or from the well casing, or from metal debris (such as pump bowls, pump columns, shafts, drop pipes, and strainers) that might have fallen to the bottom of the well. Because the EPA standard analytical procedures for priority pollutants require analysis for total concentrations, any such particulate matter would not be filtered from the sample but would be totally digested in acid before the chemical analysis was done. Thus, analytical results might not be representative of the amounts of the constituents dissolved in the aquifer water. Resampling and analysis for both total and dissolved fractions will be needed to verify the occurrence of excessive concentrations of lead and nickel in water from these wells.

Other Constituents

None of the parameters listed under the title of "Other Constituents" in table 5 were found in excessive concentrations. Constituents like methylene blue active substance and boron were included in the analyses because they could be indicators of landfill leachate. The two samples that had elevated amounts of boron (120 µg/L) came from Well 19 (MCAS Well 6) and Well 74 (MCAS Well 9). These wells tap the deeper parts of the aquifer which are likely to contain larger proportions of saltwater. This water may be the source of the boron as well as the elevated sodium and chloride concentrations mentioned earlier.

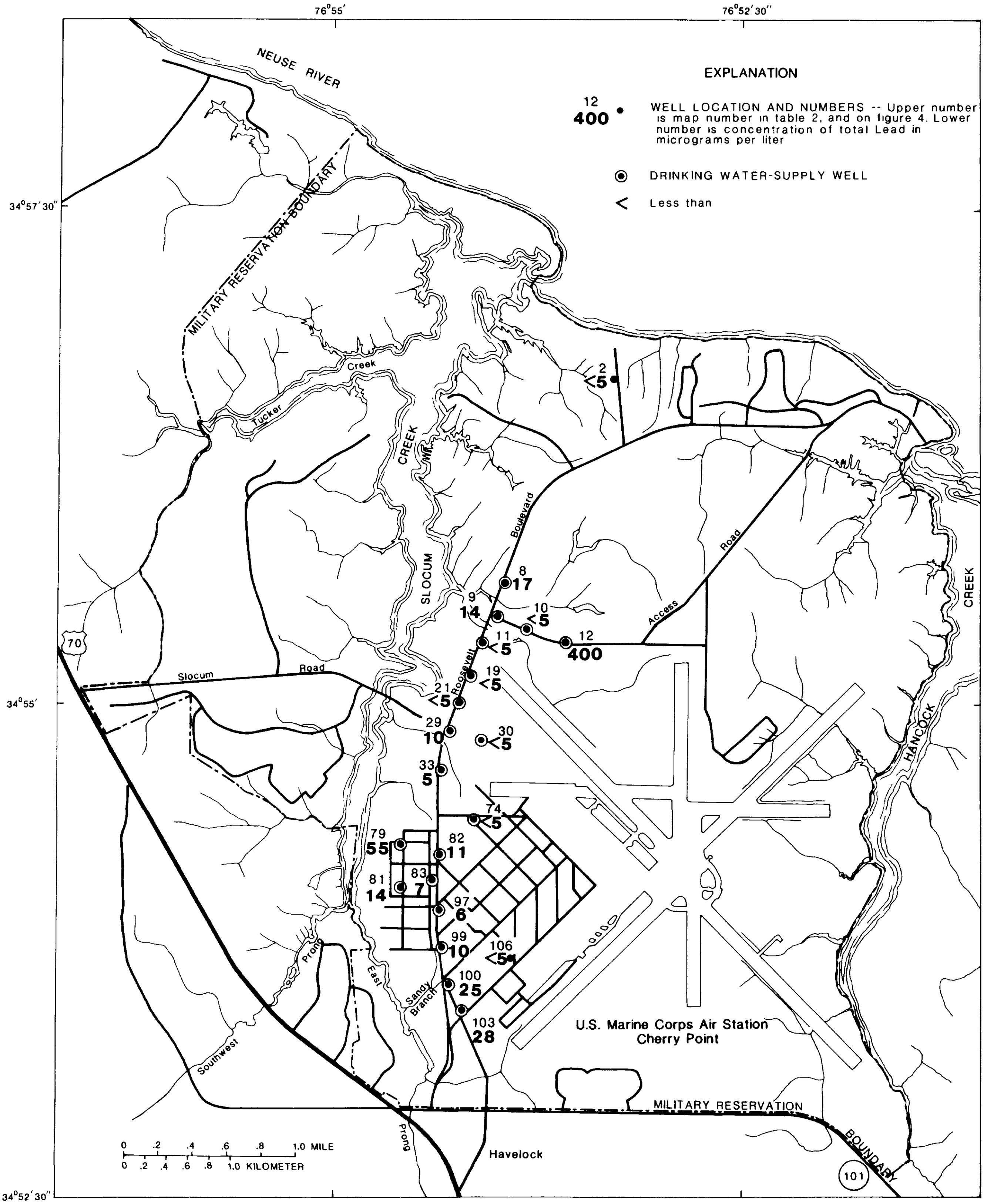

Figure 12.--Concentrations of lead in water from wells in the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina.

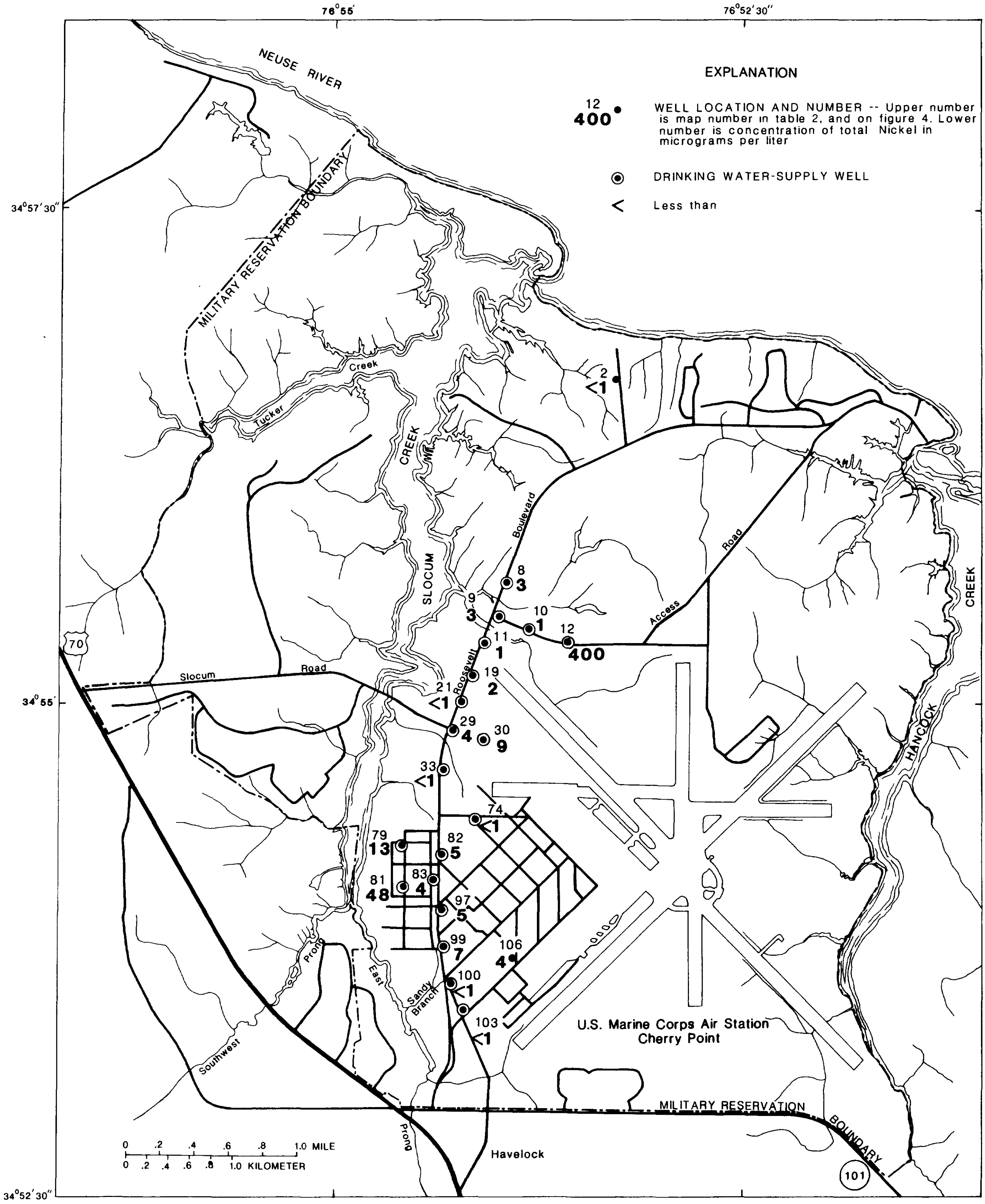

Figure 13.--Concentrations of nickel in water from wells in the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina.

Results

In summary, table 5 indicates the raw, untreated water sampled from the supply wells at the Air Station is a naturally hard, calcium-bicarbonate type water, containing dissolved-solids concentrations of about 300 mg/L, with a pH of about 7.25. Concentrations of dissolved iron and manganese in the water from most wells exceed drinking water standards, but this commonly occurs in the Castle Hayne aquifer throughout the region. Elevated amounts of chloride and boron occur in water from the deepest supply wells at the Air Station, Wells 19 and 74 (MCAS Wells 6 and 9, respectively). Existing data suggest that there has been a four-fold increase in chloride (from 10 to 43 mg/L) in water from Well 19 during the period from 1942 to 1986. The source of the boron and chloride is believed to be due to larger proportions of saltwater that occur in the deeper part of the Castle Hayne aquifer that is being tapped by these supply wells. The increase in chloride is probably caused by the upward movement or upconing of saltwater which is induced by lowering of the hydraulic head in the aquifer as a result of pumping water from all the supply wells tapping the Castle Hayne aquifer.

Excessive concentrations of total lead (more than 50 µg/L) were found in water from Wells 79 and 12 (55 and 400 µg/L, respectively), and excessive concentrations of total nickel (more than 13.4 µg/L) were found in Wells 81 and 12 (48 and 400 µg/L, respectively). These high concentrations may have come from the laboratory digestion of clay and metal particles that were picked up by the bailer from inside the well during the sampling process. Resampling will be needed to verify the analytical results for lead and nickel in water from these wells.

Organic Constituents

Priority Pollutant Organic Compounds and Organic Pesticides

Perhaps the most important finding of this study in terms of public safety and health is the possible presence of several priority pollutant organic compounds and organic pesticides in water samples collected from supply wells on the Air Station. The many types of compounds for which analyses were made have been described in the previous sections and are listed in table 3 in the basic data section. Those analyses which produced positive identifications of priority pollutant organic compounds and organic pesticides in concentrations at or above the analytical detection limit for the particular chemical compound are summarized in table 6. Positive identifications were made on samples from 11 of 21 wells.

Of the six priority pollutant organic compounds presented in table 6, the first five (dichlorobromomethane, chlorodibromomethane, chloroform, toluene, and benzene) are purgeable (volatile) compounds, and the sixth (di-n-octyl phthalate) is a base/neutral extractable compound. The three pesticides (parathion, methyl parathion, and methyl trithion) are organophosphorus compounds used as insecticides. The presence of these insecticides in water from Wells 19 (MCAS Well 6) and 81 (MCAS Well 19) has been called into question because of a possible analytical interference at the laboratory (James W. Bobo, Tennessee Valley Authority, Laboratory Branch, written commun., December 11, 1986).

Similarly, the occurrence of dichlorobromomethane, chlorodibromomethane, and chloroform in water from Well 103 (MCAS Well 17) is unusual and not easily explained for untreated ground water. These three compounds,

Table 6.--Priority pollutant organic compounds and organic pesticides detected in water from wells in the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina

[All constituent concentrations given in micrograms per liter. DWS, drinking water-supply well; IRS, irrigation-supply well]

Map well number (fig. 4)	Cooperator well number	Use	Priority pollutant organic compounds						Organic pesticides		
			Dichlorobromo-methane	Chlorodibromo-methane	Chloroform	Toluene	Benzene	Di-n-octyl phathalate	Parathion	Methyl parathion	Methyl trithion
2	27	IRS	--	--	--	--	0.2	38.0	--	--	--
9	21	DWS	--	--	--	--	.2	--	--	--	--
19	6	DWS	--	--	--	--	--	--	0.02*	0.06*	0.18*
33	8	DWS	--	--	--	--	.4	--	--	--	--
79	13	DWS	--	--	--	--	.9	--	--	--	--
81	19	DWS	--	--	--	0.2	.9	--	--	.07*	--
83	12	DWS	--	--	--	--	.9	--	--	--	--
97	14	DWS	--	--	--	--	.3	--	--	--	--
99	15	DWS	--	--	--	--	1.9	--	--	--	--
100	16	DWS	--	--	--	--	1.4	--	--	--	--
103	17	DWS	0.3	0.3	0.6	--	1.7	--	--	--	--

*The organophosphorus pesticides parathion, methyl parathion, and methyl trithion in samples from Wells 19 and 81 are questionable due to a possible analytical interference (James W. Bobo, Tennessee Valley Authority, Laboratories Branch, written commun., December 11, 1986.)

collectively known as trihalomethanes, are not unusual, however, in treated drinking water derived from surface-water sources. The trihalomethanes are formed following chlorination when the chlorine reacts with naturally occurring organic compounds in the raw water. The occurrence of chloroform has been reported in two shallow observation wells (NUS Corp., 1986) across Roosevelt Boulevard from Well 103 (MCAS Well 17). Thus, there may be some connection between the trihalomethanes in water from the deep well and the presence of chloroform in water from the shallow wells. Verification of the presence of these six compounds will depend on resampling and analysis of water from the appropriate wells.

The most frequently detected priority pollutant organic compound was benzene which was identified in water from 10 of the 21 wells sampled. All benzene concentrations were below the 5 µg/L maximum contaminant level set by the EPA for drinking water. The three highest measured concentrations were 1.9, 1.7, and 1.4 µg/L in Wells 99, 103, and 100 (MCAS Wells 17, 15, and 16, respectively). Samples from three other wells contained 0.9 µg/L of benzene; lesser amounts were found in water from the four other wells in which benzene was detected. When the benzene data are plotted on a well location map, the concentrations can be contoured to show an area of high benzene concentration located in the southern part of the Air Station along Roosevelt Boulevard between Slocum Road and Highway 101 (fig. 14). As shown in figure 14, the highest benzene concentrations center about Sandy Branch which drains southwestward through a major facilities and equipment maintenance area into the East Prong of Slocum Creek.

The three wells with the highest concentrations of benzene are also within 0.4 mi of the landfill site on Sandy Branch (waste-disposal or spill site 15 in fig. 2) in which Putnam and others (1982) report that as much as 20,000 gallons of oil may have been disposed of between 1946 and 1948, and perhaps as recently as 1949. NUS Corporation (1986) also reports that ground water from the surficial aquifer in the area of landfill Site 16 (fig. 2, this report), and between Site 16 and water-supply wells 100 and 103 (MCAS Wells 16 and 17), contains several volatile solvents and organic chemicals in concentrations between 100 and 300 µg/L and one determination of trans-1,2-dichloroethene at 2,000 µg/L. Volatile solvents and organic chemicals detected by NUS Corporation (1986) at this site also include trichloroethene, chloroform, toluene, and 1,1,2,2-tetrachlorethane. Although NUS Corporation (1986) did not report benzene in the shallow ground water in the area of Site 16 and Sandy Branch, there is probably a correlation between the oil disposal at Site 16, the elevated levels of solvents in the surficial aquifer near Sandy Branch, the proximity of the maintenance areas east of Roosevelt Boulevard, and the benzene contamination noted by this report in the Castle Hayne aquifer in the southern part of the Air Station.

Benzene and the trihalomethanes are fairly soluble in water for organic compounds (Weast, 1975), have low octanol-water partitioning coefficients indicating a low degree of uptake by soil organic matter (Chiou and others, 1977), have a fairly low attraction for clays or other inorganic sedimentary particles, and, thus, can be expected to be mobile in the hydrologic system.

The EPA (1986) water-quality criterion for benzene is 0.66 µg/L which is the concentration that could be expected to result in one cancer case per million people over a lifetime. Samples from six wells exceeded this value. None of the concentrations exceeded the EPA maximum contaminant level which has recently been set at 5 µg/L (U.S. Environmental Protection Agency, 1987).

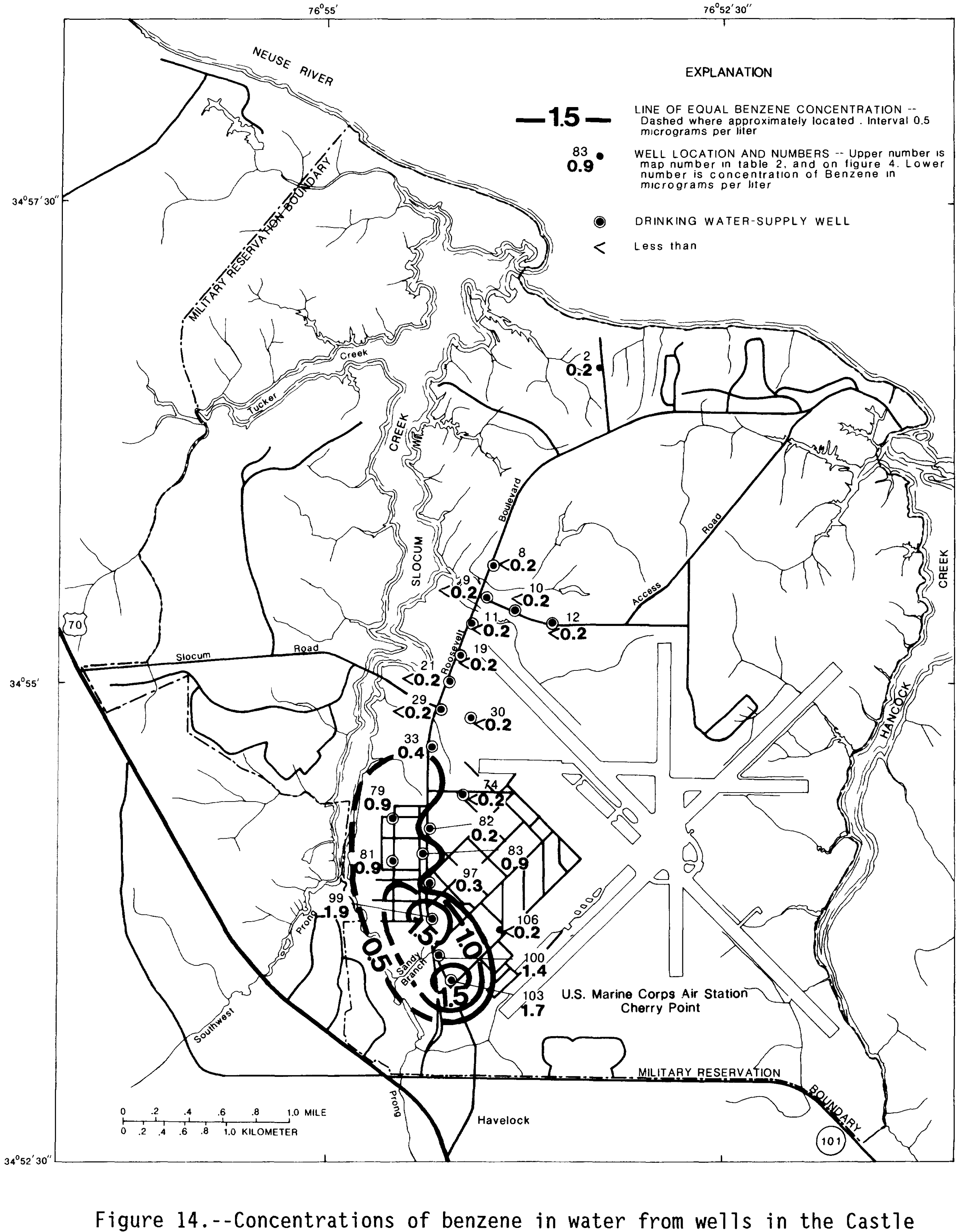

Figure 14.--Concentrations of benzene in water from wells in the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina.

Two other organic priority pollutants, toluene, and di-n-octyl phathalate, were detected at or above the detection limit but are well below the EPA (1986) water-quality criteria (table 3) for these substances. The toluene was found in water from Well 81 (MCAS Well 19) which taps the Castle Hayne aquifer in the proximity of landfill site 10. NUS Corporation (1986) found excessive concentrations of toluene in water from monitoring wells that tap the surficial aquifer at site 10, and there is probably a correlation between this shallow contamination and the occurrence of toluene in the deep-well water.

Nonpriority Pollutant Organic Compounds

During the analyses for priority pollutant organic compounds (purgeables and extractables), which utilizes a gas chromatograph-mass spectrometer (GC-MS) to detect organic substances of different molecular structure and weight, a number of compounds were detected that were not on the priority pollutant list. In an effort to identify these compounds, a comparison, or library search, was made between the spectra of the unknown compounds produced by the GC-MS and a compilation of approximately 39,000 available spectra of known compounds. Libraries of available spectra are maintained by the National Bureau of Standards (NBS) and Environmental Protection Agency with the National Institutes of Health (EPA-NIH).

The results of the library search and spectral comparisons are tabulated in table 7. Nearly all of the unknown compounds have been identified with a high percentage probability of identification as shown in table 7. Water from three wells (numbers 9, 10, and 11) contains a purgeable compound that could not be identified. A comparison of the GC-MS spectra for samples from these three wells suggests that the unidentified compound is the same compound in all three samples. The concentration of this unknown purgeable compound is very low in all three samples. Because of the very low concentrations, further analysis probably will not yield a positive identification of this compound.

Nearly all of the extractable compounds listed in table 7 occur in, or are derived from compounds that occur in, fats and oils of land animals, marine animals, and plants. Some, like octadecanoic acid (stearic acid), hexadecanoic acid (palmitic acid), and dodecanoic acid (lauric acid) are saturated fatty acids common to fats and oils from a variety of animals and plants (Weast, 1975, p. D216-D217). Thurman (1985, p.118) indicates that various fatty acids in ground water may be derived from the fermentation of solid wastes. Much like benzene and the trihalomethanes discussed earlier, the fatty acids and related compounds are moderately soluble in water (Weast, 1975), have low octanol-water partitioning coefficients (Chiou and others, 1977), have a fairly low attraction for clays or other sedimentary particles, and, thus, can be expected to be somewhat mobile in the hydrologic system.

Although nonpriority pollutant organic compounds were found in samples from supply wells extending from Well 8 (MCAS Well 22) on the north to Well 100 (MCAS Well 16) on the south, there is a concentration of wells near the intersection of Roosevelt Boulevard and Slocum Road from which the majority of these compounds were identified. These are Wells 19, 21, 29, and 33 (fig. 2). Well 33 (MCAS Well 8) contained the greatest variety of compounds at six (table 7), and had the highest concentrations with a maximum 28 µg/L of 4,7-dimethylundacene.

Table 7.--Nonpriority pollutant organic compounds detected in water from wells in the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina

[Compounds identified by a U.S. Environmental Protection Agency-National Institute of Health or National Bureau of Standards library search of approximately 39,000 available spectra. DWS, drinking water-supply well; IRS, irrigation-supply well; µg/L, micrograms per liter]

Map well number (fig. 4)	Cooperator well number	Use	Nonpriority pollutant organic compounds				
			Acid extractable and base/neutral extractable compounds			Purgeable (volatile) compounds	
			Compound	Percent probability of identification[1]	Approximate concentration (µg/L)	Compound	Approximate concentration (µg/L)
2	27	IRS	None	--	--	None	--
8	22	DWS	Octadecanoic acid, butyl ester	95	1	None	--
9	21	DWS	None	--	--	One unidentified	>Trace
10	23	DWS	None	--	--	One unidentified	Trace
11	5	DWS	None	--	--	One unidentified	.2
12	25	DWS	None	--	--	None	--
19	6	DWS	Octadecanoic acid, butyl ester	71	2	None	--
21	7	DWS	Hexadecanoic acid, butyl ester	51	Trace (<1)	None	--
			Octadecanoic acid, butyl ester	71	Trace (<1)	--	--
29	4	DWS	Octadecanoic acid, butyl ester	80	2	None	--
			Hexadecanoic acid, dioctyl ester	74	3	--	--
30	3	DWS	None	--	--	None	--
33	8	DWS	Octane, 4 methyl	67	18	None	--
			Undecane, 4,7 dimethyl	78	28	--	--
			Dodecanoic acid	93	5	--	--
			1-hexadecanol	89	15	--	--
			Hexadecane, 2,6,10,14 tetramethyl	70	3	--	--
			Docosane	67	3	--	--
74	9	DWS	None	--	--	None	--
79	13	DWS	None	--	--	None	--
81	19	DWS	Octadecanoic acid	72	1	None	--
82	11	DWS	None	--	--	None	--
83	12	DWS	None	--	--	None	--
97	14	DWS	None	--	--	None	--
99	15	DWS	None	--	--	None	--
100	16	DWS	1-hexadecanol	91	1	None	--
103	17	DWS	None	--	--	None	--
106	26	IWS	None	--	--	None	--

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[1] Reported by Tennessee Valley Authority, Laboratories Branch.

These wells are in an area of fuel tank farms, known spills, and landfills (fig 2). Well 33 (MCAS Well 8) is across Roosevelt Boulevard from Site 10 (fig. 2) which was the primary landfill for the Air Station from 1955 to at least 1982 (Putnam and others, 1982); it is the largest landfill on the Air Station. This landfill received the "complete spectrum of wastes" (Putnam and others, 1982) generated on the Air Station, including petroleum, oil, and lubricants, and hazardous wastes. Thus, it is presumed that household wastes from residences and dining halls, including food residue, grease, and cooking oil, were also disposed of at this site. Ground-water contamination in the surficial aquifer is known to occur at Site 10 (Putnam and others, 1982; NUS Corp., 1986). Due to the proximity of Wells 19, 21, 29, and 33 (MCAS Wells 6, 7, 4, and 8, respectively) to a number of known and suspected sources of ground-water contamination, it is not surprising that organic chemicals were found in water from these wells.

Results

A variety of organic compounds, both synthetic and natural, were found in water samples collected from supply wells at the Air Station. The total number of identifiable organic compounds found in individual supply wells is summarized in table 8. The number of compounds ranged from zero to as many as seven in Well 33 (MCAS Well 8). Of the 21 wells sampled, 14 contained identifiable organic compounds in concentrations from trace to 38.0 µg/L.

The distribution and types of organic compounds in water from the supply wells indicate that the apparent contamination of ground water in the Castle Hayne aquifer generally occurs in two separate areas and is of two different types. The most important, in terms of a known hazard to health, is an area of benzene contamination that centers on Wells 99, 100, and 103 (MCAS Wells 15, 16, and 17, respectively, fig. 2) at the southern end of Roosevelt Boulevard between Slocum Road and Highway 101. Benzene is on the EPA list of priority pollutants (table 4) and is a known carcinogen. Measured benzene concentrations in these wells are 2 to 3 times higher than the criterion level of 0.66 µg/L for drinking water established by EPA (1986); however, no samples were found to contain concentrations as high as the maximum contaminant level of 5 µg/L.

The area where water from the supply wells is contaminated by benzene coincides with the area where the clay confining units between land surface and the top of the Castle Hayne aquifer are thin and (or) discontinuous. Sandy Branch, which drains the core of the developed and industrial area (Putnam and others, 1982, fig. 5-5) at the Air Station, cuts completely through the upper confining unit in the area near Well 100 (MCAS Well 16, pl. 1) and, thus, could be providing a route for the source of the contamination found in the well water.

A second area of contamination seems to center on Wells 19, 21, 29, and 33 (MCAS Wells 6, 7, 4, and 8, respectively, fig. 2) near the intersection of Roosevelt Boulevard and Slocum Road. Most of the organic compounds identified in water from these wells are fatty acids and their derivatives, which are not on the EPA priority pollutant list (table 4).

The area where water from wells in the Castle Hayne aquifer is contaminated by fatty acids and derivatives occurs where there are a number of known and potential sources of ground-water contamination that could include these substances. The largest is the landfill (Site 10, fig. 2), which received wastes from all over the Air Station for more than 25 years.

Table 8.--Total number of organic chemicals identified in water from wells in the Castle Hayne aquifer, U.S. Marine Corps Air Station, Cherry Point, North Carolina

[DWS, drinking water-supply well; IWS, industrial water-supply well; IRS, irrigation-supply well]

Map well number (fig. 4)	Cooperator well number	Use	Priority pollutants and pesticides	Nonpriority pollutants from NBS library search	Total
2	27	IRS	2	0	2
8	22	DWS	0	1	1
9	21	DWS	1	0	1
10	23	DWS	0	0	0
11	5	DWS	0	0	0
12	25	DWS	0	0	0
19	6	DWS	3	1	4
21	7	DWS	0	2	2
29	4	DWS	0	2	2
30	3	DWS	0	0	0
33	8	DWS	1	6	7
74	9	DWS	0	0	0
79	13	DWS	1	0	1
81	19	DWS	3	1	4
82	11	DWS	0	0	0
83	12	DWS	1	0	1
97	14	DWS	1	0	1
99	15	DWS	1	0	1
100	16	DWS	1	1	2
103	17	DWS	4	0	4
106	26	IWS	0	0	0

Other possible sources are the site of the former incinerator (Site 7, fig. 2), waste oil storage area (Site 5, fig. 2), fuel storage and handling areas and spills (fig. 2). Although the chemicals detected in water from these wells do not generally pose a threat to health, they do indicate that contaminated water has moved into the aquifer from shallower sources of contamination. Thus, the possibility exists that other, more hazardous chemicals known to occur in the surficial aquifer in this area (NUS Corp., 1986), may eventually migrate into the Castle Hayne aquifer in response to continued pumping. Although the confining units in this area are nearly twice as thick as those beneath the Sandy Branch drainage area, the greater number of potential sources of contamination may offset the benefit of the thicker confining units.

The possible routes of contamination from the surficial to the Castle Hayne aquifer are probably not limited to movement through the intervening sediments but may include routes through or along well casings damaged mechanically or by corrosion, poorly constructed and grouted wells, and improperly destroyed or abandoned wells. It is also possible that contaminants could make their way into the Castle Hayne aquifer by the deliberate or inadvertent disposal of wastes into abandoned (unused wells) or from compounds introduced during maintenance, rehabilitation, or other work performed on the operational wells.

SUMMARY AND CONCLUSIONS

The U.S. Marine Corps Air Station at Cherry Point, North Carolina, is located in the Coastal Plain province and is underlain by about 2,500 ft of unconsolidated to partially consolidated beds of sand, silt, clay, shell, limestone, and sandy limestone that range in age from Quaternary to Cretaceous. These sedimentary deposits make up a number of aquifers and confining units that are saturated with freshwater from the water table near or at land surface to about 500 ft below land surface, and with saltwater at greater depths.

As shown in east-west and north-south hydrogeologic sections, four freshwater aquifers underlie the Air Station. The upper three aquifers are composed primarily of sand and occur between land surface and about 95 ft below land surface. These units are the surficial, Yorktown, and Pungo River aquifers in order of increasing depth and age. The fourth and deepest aquifer, the Castle Hayne aquifer, is composed primarily of limestone and sandy limestone and occurs between about 115 ft and 700 ft below land surface. The aquifers are separated by three confining units that have an aggregate thickness that ranges from over 70 ft in the north-central part of the Air Station to about 20 ft in the southern part where the confining units are thin and (or) discontinuous.

The Air Station obtains its water supply from wells that tap the Castle Hayne aquifer at depths that range from about 195 to 330 ft below land surface. Many of these wells are located near landfill sites that have been used to dispose of considerable amounts of hazardous waste generated by aircraft refitting the parts-manufacturing operations at the Air Station. These substances have contaminated ground water in the surficial and Yorktown aquifers beneath and adjacent to the landfills.

Large amounts of ground water have been pumped from the supply wells for over 45 years. At present, ground-water withdrawals are estimated to be between 2.5 and 4.5 Mgal/d. The withdrawals have lowered the potentiometric surface of the Castle Hayne aquifer around the active production wells so that it is as much as 30 ft lower than the water table.

The water-level declines in the Castle Hayne aquifer have reversed the hydraulic gradient that existed during prepumping conditions in much of the area. Now, some of the ground water that would have flowed from the Castle Hayne into the shallower aquifers to discharge into the nearby creeks and rivers has been diverted to the supply wells. The present hydraulic gradients create a potential for the downward movement of some contaminated ground water from the surficial aquifer to the Castle Hayne aquifer and the upward movement of some saltwater from the deep part of the Castle Hayne aquifer.

Results of water-quality analyses made on samples collected from 21 of the supply wells at the Air Station indicate that water from the Castle Hayne aquifer is a naturally hard, calcium-bicarbonate type, with relatively high concentrations of silica, a median dissolved-solids concentration of 300 mg/L, and a median pH of 7.25. Concentrations of iron and manganese (median values of 780 and 79 ug/L, respectively) in excess of drinking water-quality criteria were found to be common. It is suspected that high concentrations of lead and nickel (as much as 400 ug/L) detected in water from the Castle Hayne may have come from clay and metal particles that may have gotten into the samples by the bailer dislodging these particles from the sides of the wells, and (or) from any metallic debris that may have fallen into the wells. Resampling and analysis would be needed to verify the analytical results for lead and nickel in water from these wells.

Elevated amounts of chloride (as much as 43 mg/L) and boron (as much as 120 µg/L), relative to amounts detected in most of the samples, occur in water from Wells 19 and 74, which are among the deepest on the Air Station (MCAS Wells 6 and 9, respectively). Historical water-quality data indicate that there may have been a progressive four-fold increase in chloride in water from Well 19 during the period from 1942 to 1986. The source of the chloride and boron and the increase in the chloride are probably from the upward movement of some saltwater from the deeper parts of the Castle Hayne aquifer, which is induced by pumping in the upper parts of the Castle Hayne aquifer.

The distribution and types of organic compounds detected in the water samples from 14 of 21 supply wells indicate that there has been contamination of ground water in the Castle Hayne aquifer generally in two separate areas and that the contamination is of two different types. The most important, in terms of containing a known hazard to health, is an area of benzene contamination that centers on Wells 99, 100, and 103 (MCAS Wells 15, 16, and 17, respectively), at the southern end of Roosevelt Boulevard between Slocum Road and State Highway 101. Benzene concentrations in water from these wells are as much as 1.9 µg/L, or about 40 percent of the current maximum contaminant level for this priority pollutant. The probable sources of the benzene are from the industrial area and hazardous-waste sites 15 and 16 where oil and several volatile solvents and organic chemicals have been disposed of or spilled in the past. It is likely that the thin and (or) discontinuous nature of the confining units in this area is an important contributing factor to this apparent contamination. In addition, Sandy Branch, which drains the core of the developed and industrial area at the Air Station, cuts completely through the upper confining unit in this area and, thus, could be providing a route for the source of the contamination found in the well water. Resampling would be needed to verify the analytical results for the concentrations of benzene in water from the supply wells.

The second area of contamination centers around Wells 19, 21, 29, and 33 (MCAS Wells 6, 7, 4, and 8, respectively), near the intersection of Roosevelt Boulevard and Slocum Road. In this area, water from the supply wells contains as much as 28 µg/L of fatty acids and their derivatives. The possible sources for these nonpriority pollutant substances include landfill Site 10, which received wastes from all throughout the Air Station for 25 years; Site 7, site of the former incinerator; and Site 5, a waste-oil storage area. Although these chemicals do not pose a threat to health, their apparent presence in the well water does indicate that contaminated water has moved into the Castle Hayne aquifer from sources of contamination in the surficial and Yorktown aquifers. Thus, the possibility exists that other more hazardous chemicals known to occur in the shallow deposits in this area may eventually migrate into the Castle Hayne aquifer in response to continued pumping.

The possible routes of contaminants from their sources at land surface to the Castle Hayne aquifer are both natural and manmade. The routes include movement through the natural sediments that underlie the area, and mechanically damaged or corroded well casing, poorly grouted or improperly abandoned wells, and even the wells that are currently operational at the Air Station.

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page 53 follows

BASIC DATA

This section includes the basic data from which this report was prepared.

Table 2.--Records of selected wells

[Cooperator well number(s): Number(s) which has been previously assigned by the U.S. Marine Corps or its contractors to identify wells constructed at the Air Station. Where more than one number appears, first number is the most current usage. USGS identification number: Numbers are comprised of degrees, minutes, and seconds of latitude (first six numbers) north of the equator, and longitude (next seven numbers) west of the zero meridian. Number right of decimal point is a sequential number for wells at designated location. Use: ABD, abandoned; DWS, drinking-water supply; IRS, irrigation supply; IWS, industrial supply; COOL, cooling-water supply; M, monitoring and (or) observation well; GTW, geothermal test well. (e), indicates values estimated from 7.5 minute quadrangle map. WT, surficial and (or) unconfined Yorktown aquifer; PR, Pungo River aquifer; CH, Castle Hayne aquifer. galv., galvanized metal casing; PVC, polyvinylchloride casing. OH, open hole; OE, open end; S, screen, screen length is total depth minus casing length. S, static (nonpumping) water level; P, pumping water level. Yes, water-quality data are available; No, water-quality data are not available. G, geophysical log; L, lithologic log. C&O, Cobb and others (1979); F&L, Floyd and Long (1970); NUS, NUS Corporation (1986) and (1987); S&C, Sharpless and Coble (1983a); Snbl, Schnabel (1981); USGS, U.S. Geological Survey files; USMC, U.S. Marine Corps files. "--", indicates no data available.]

Map well number (fig.4)	Cooperator well number(s)	USGS identification number	Use	Land surface altitude above sea level (feet)	Aquifer	Total well depth below land surface (feet)	Casing length (feet)	Diameter (inches) and casing material	Finish	Water level above or below (-) sea level (feet)	Date of water-level measurement	Height of measuring point above or below (-) land surface (feet)	Water-quality analysis	Geophysical or lithological log	Data source	Remarks
1	26	3456430765247.1	--	27(e)	CH	200	--	4	OH	8(e)	--	--	No	G	F&L	Destroyed(?)
2	27	3456390765316.1	IRS	26.0(e)	CH	235	200	10	OH	3.7S(e)	3/24/87	1.6	Yes	G,L	USMC;USGS	
3	24	3456310765142.1	--	18.6	CH	130	112	4	--	6.12	12/47	0.5	No	--	USMC	Destroyed(?)
4	1GW03	3456140765207.1	M	9.9	WT	25	10	2	S	4.35	3/25/87	1.3	Yes	--	NUS	
5	1GW04	3456090765211.1	M	21.6	WT	40	30	2	S	5.32	3/25/87	1.5	Yes	L	NUS	
6	1GW01	3456070765217.1	M	25.3	WT	25	10	2	S	12.06	3/25/87	1.3	Yes	--	NUS	
7	20	3455450765412.1	--	25.0	PR	185	181	6	OH	10.01	12/47	1.9	Yes	L	USMC	Destroyed(?)
8	22	3455370765357.1	DWS	21.9	CH	236	160	8	OH	-3.0P	3/24/87	2.6	Yes	G,L	USMC;USGS	
9	21	3455270765400.1	DWS	12.0	CH	224	150	8	OH	7.4S	3/24/87	1.8	Yes	G,L	USMC;USGS	
10	23	3455230765348.1	DWS	26.2	CH	219	181	8	OH	-4.0P	3/24/87	2.4	Yes	G,L	USMC;USGS	
11	5; 60	3455190765405.1	DWS	12.9	CH	223	211	8	OH	3.1S	3/24/87	-4.3	Yes	G,L	F&L;USMC; USGS	
12	25; 24	3455200765338.1	DWS	25.2	CH	253	234	8	OH	-19.7P	3/24/87	2.0	Yes	G,L	USMC;USGS	
13	24A	3455200765338.2	M	25.2	WT	22	20	2 galv.	S	11.22	3/27/87	0.6	No	--	USGS	
14	4GW01	3455160765329.1	M	22.4	WT	25	10	2	S	11.68	3/25/87	1.5	Yes	--	NUS	
15	4GW04	3455080765330.1	M	19.9	WT	25	10	2	S	9.47	3/25/87	2.2	Yes	--	NUS	
16	4GW05	3455040765331.1	M	21.2	WT	25	10	2	S	8.54	3/25/87	1.9	Yes	--	NUS	
17	4GW02	3455050765342.1	M	10.5	WT	25	10	2	S	6.63	3/25/87	1.5	Yes	--	NUS	
18	4GW03	3455100765346.1	M	16.6	WT	25	10	2	S	7.78	3/25/87	0.9	Yes	--	NUS	
19	6; 59	3455090765409.1	DWS	25.5	CH	329	303	8	OH	10.4S 3.7S	Fall 1941 3/24/87	-5.2	Yes	G,L	F&L;USMC; USGS	
20	32	3454590765407.1	--	24.3	PR	90	84	4	OH	8.04	12/47	1.5	Yes	L	USMC	Destroyed(?)
21	7; 58	3455000765414.1	DWS	14.3	CH	251	239	8	OH	9.8S -7.9P	Fall 1941 3/24/87	2.7	Yes	G,L	F&L;USMC; USGS	

Table 2.--Records of selected wells--Continued

Map well number (fig.4)	Cooperator well number(s)	USGS identification number	Use	Land surface altitude above sea level (feet)	Aquifer	Total well depth below land surface (feet)	Casing length (feet)	Diameter (inches) and casing material	Finish	Water level above or below (-) sea level (feet)	Date of water-level measurement	Height of measuring point above or below (-) land surface (feet)	Water-quality analysis	Geophysical or lithological log	Data source	Remarks
22	5GW05	3454590765425.1	M	16.6	WT	25	10	2	S	8.53	3/25/87	1.9	Yes	--	NUS	
23	5GW07	3455020765429.1	M	6.4	WT	10	3	2	S	3.80	3/25/87	1.3	Yes	L	NUS	
24	5GW02	3455010765429.1	M	8.2	WT	25	10	2	S	4.74	3/25/87	1.7	Yes	--	NUS	
25	6GW04(?)	3454580765434.1	M	8.4	WT	25	10	2	S	3.90	3/25/87	1.1	Yes	--	NUS	
26	20; 19	3454570765427.1	ABD	15.6	CH	275	275	6	OE	11.7S 4.8S	Fall 1941 3/24/87	1.1	No	G,L	F&L;USMC; USGS	Used as an observation well
27	6GW01	3454550765426.1	M	15.3	WT	25	10	2	S	8.79	3/25/87	1.2	Yes	--	NUS	
28	5GW01	3454570765427.1	M	15.8	WT	25	10	2	S	8.73	3/25/87	1.4	Yes	--	NUS	
29	4; 50	3454510765417.1	DWS	21.0	CH	308	294	8	OH	10.1S 3.1S	Fall 1941 3/24/87	2.3	Yes	G,L	F&L;USMC; USGS	
30	3; 55	3454490765405.1	DWS	21.3	CH	230	213	8	OH	10.4S 2.3P	Fall 1941 3/24/87	1.2	Yes	G,L	F&L;USMC; USGS	
31	2; 56	3454470765354.1	ABD	24.4	CH	242	228	8	OH	10.0S 3.9S	Fall 1941 4/66	1.5	No	L	F&L;USMC	Well destroyed
32	1; 57	3454440765342.1	ABD	21.8	CH	240	222	8	OH	9.8S 3.0S	Fall 1941 2/65	1.6	No	L	F&L;USMC	Well destroyed
33	8; 51	3454400765420.1	DWS	21.8	CH	195	189	8	OH	10.3S -8.6P	Fall 1941 3/24/87	1.9	Yes	G,L	F&L;USMC; USGS	
34	GS6	3454410765421.1	M	21.8	WT	17	15	2	S	11.98	3/24/87	0.8	No	--	S&C	
35	10EGW20	3454390765425.1	M	22.8	WT	20	15	2	S	11.83	3/26/87	0.9	No	L	S&B;Snbl	Well 18 in S&C (1983a)
36	SNBL8	3454430765427.1	M	23.3	WT	21.4	20	2	S	9.46	1/26/83	0.5	No	--	Snbl	
37	10GW04	3454440765440.1	M	15.6	WT	25	10	2	S	4.68	3/25/87	1.5	Yes	L	NUS	
38	10EGW02	3454400765441.1	M	19.6	WT	21.5	16.5	2	S	3.88	3/25/87	0.6	Yes	--	Snbl;NUS	
39	10EGW03	3454360765441.1	M	15.4	WT	21.5	16.5	2	S	3.02	3/25/87	0.9	Yes	--	Snbl;NUS	
40	10GW17	3454380765430.1	M	24.6	WT	24.5	14.5	2	S	8.57	3/26/87	2.7	Yes	L	NUS	
41	10EGW05	3454370765431.1	M	21.7	WT	19.7	15	2	S	8.35	3/25/87	1.9	Yes	--	Snbl;NUS	
42	10EGW06	3454370765431.2	M	22.0	WT	33.3	30	2	S	8.28	3/25/87	1.6	Yes	--	Snbl;NUS	
43	10EGW07	3454370765431.3	M	22.0	WT(?)	46.6		2	S	8.30	3/25/87	1.5	Yes	--	Snbl;OUS	
44	10GW19	3454370765431.4	M	13.3	WT	20	10	2	S	7.93	3/25/87	1.8	Yes	L	NUS	
45	10GW21	3454370765431.5	M	13.2	WT	30	20	2	S	7.48	3/25/87	2.6	No	L	NUS	
46	10GW23	3454370765431.6	M	22.4	PR	83	73	2	S	6.55	3/25/87	2.0	Yes	L	NUS	
47	10GW24	3454370765431.7	M	13.3	PR	70	60	2	S	6.06	3/25/87	2.5	Yes	L	NUS	
48	10EGW08	3454380765429.1	M	24.1	WT	40.8	-	2	S	8.43	3/26/87	0.7	Yes	--	NUS	
49	10GW14	3454380765429.2	M	23.9	WT	25	15	2	S	8.74	3/26/87	1.9	Yes	L	NUS	
50	10GW15	3454380765429.3	M	23.9	WT	35	25	2	S	8.71	3/26/87	2.4	Yes	L	NUS	
51	10GW16	3454380765429.4	M	24.1	PR	44	34	2	S	7.80	3/26/87	0.9	Yes	L	NUS	
52	10GW18	3454370765429.1	M	21.3	WT	25	15	2	S	8.45	3/25/87	1.3	Yes	L	NUS	
53	10GW22	3454370765429.2	M	21.4	PR	83	73	2	S	8.91	3/25/87	2.2	Yes	L	NUS	
54	GS8	3454370765429.3	M	20.7	WT	17.9	15	2	S	8.30	3/25/87	1.1	No	--	S&C	
55	10GW12	3454330765437.1	M	25.1	WT	25	10	2	S	10.26	3/26/87	1.1	Yes	L	NUS	

Table 2.--Records of selected wells--Continued

Map well number (fig.4)	Cooperator well number(s)	USGS identification number	Use	Land surface altitude above sea level (feet)	Aquifer	Total well depth below land surface (feet)	Casing length (feet)	Diameter (inches) and casing material	Finish	Water level above or below (-) sea level (feet)	Date of water-level measurement	Height of measuring point above or below (-) land surface (feet)	Water-quality analysis	Geophysical or lithological log	Data source	Remarks
56	10GW10	3454330765442.1	M	18.7	WT	25	10	2	S	5.2	3/26/87	0.9	Yes	L	NUS	
57	10GW11	3454280765444.1	M	20.3	WT	25	10	2	S	2.12	3/26/87	1.6	Yes	L	NUS	
58	GS3	3454320765431.1	M	14.9	WT	13.4	10	1.25	S	8.52	3/26/87	1.6	No	--	S&B;Snbl	Well B-103 in Snbl (1981)
59	SNBL1	3454310765427.1	M	23.4	WT	22	20	2	S	11.96	3/26/87	-1.0	No	--	S&B;Snbl	
60	SNBL19	3454320765425.1	M	22.7	WT	19	15	2	S	14.06	3/26/87	0.9	No	--	S&B;Snbl	
61	15	3454350765249.1	--	23.7	CH	220	217	6	OH	9.84	12/47	0.6	Yes	L	USMC	Destroyed(?)
62	East Runway Well	3454310765200.1	DWS?	20(e)	CH	315	--	4	--	4.5S(e)	3/27/87	1.5	No	G,L	USMC	
63	Site 16	3454290765157.1	GTW	20	--	1,016	1,018	4.5	C	--	--	--	No	G	C&O	Geothermal test well
64	14	3454250765231.1	--	25.24	PR(?)	115	108	4	OH	10.03	12/47	0.6	Yes	L	USMC	Destroyed(?)
65	16	3454240765250.1	--	25.0	CH	132	129	4	OH	9.95	12/47	0.4	Yes	L	USMC	Destroyed(?)
66	13GW01	3454250765338.1	M	24.3	WT	25	10	2	S	15.15	3/26/87	1.3	Yes	--	NUS	
67	13GW08	3454220765342.1	M	23.8	WT	25	10	2	S	15.28	3/26/87	1.5	Yes	--	NUS	
68	13GW05	3454160765335.1	M	24.8	WT	25	10	2	S	15.70	3/26/87	1.2	Yes	--	NUS	
69	34	3454140765335.1	COOL	25.3	CH	120	95	4	OH	11.10	Fall 1941	2.0	No	L	USMC	
70	33	3454150765338.1	COOL	23.4	CH	120	91.5	4	OH	11.28	Fall 1941	0.5	No	L	USMC	
71	37	3454150765342.1	COOL	24.5	PR	96	94.5	4	OH	12.5	Fall 1981	3.5	No	L	USMC	
72	18	3454170765339.1	COOL	22.6	PR	95	88	4	OH	11.50	12/47	0.5	Yes	L	USMC	
73	28	3454230765351.1	--	25.9	PR	68	63	4	OH	14.9	12/47	1.0	Yes	L	USMC	Destroyed(?)
74	9; 61	3454250765408.1	DWS	24.3	CH	299	248	8	OH	11.0S -5.6P	Fall 1941 3/24/87	3.1	Yes	G,L	F&L;USMC; USGS	
75	10; 52	3454250765421.1	ABD	24.4	CH	369	--	8		11.4S 11.9S	Fall 1941 3/24/87	1.9	Yes	G,L	F&L;USMC; USGS	Blasted at 290 ft. Sand ran up hole. Clogged well. Bowl assembly broke off in well.
76	10EGW01	3454230765424.1	M	21.2	WT	19.7	10	2 PVC	S	15.38	3/26/87	0.8	Yes	--	S&B;Snbl	Well 20 in S&C (1983a) and Snbl (1981)
77	SNBL7	3454210765435.1	M	23.5	WT	22.8	15	2 PVC	S	11.33	3/26/87	1.0	No	--	S&C;Snbl	
78	10EGW09	3454220765445.1	M	23.6	WT	17	15	2 PVC	S	8.90	3/26/87	1.7	No	--	S&C;Snbl	Well 4 in S&C (1983a) and Snbl (1981)

Table 2.--Records of selected wells--Continued

Map well number (fig.4)	Coop-erator well number(s)	USGS identi-fication number	Use	Land surface altitude above sea level (feet)	Aquifer	Total well depth below land surface (feet)	Casing length (feet)	Diameter (inches) and casing material	Fin-ish	Water level above or below (-) sea level (feet)	Date of water-level measure-ment	Height of measuring point above or below (-) land surface (feet)	Water-quality analysis	Geophysical or litho-logical log	Data source	Remarks
79	13; 17	3454180765435.1	DWS	24.6	CH	207	180	8	OH	11.3S 4.4S	Fall 1941 3/24/87	1.7	Yes	G,L	F&L;USMC; USGS	
80	GS9	3454180765435.2	M	24.6	WT	17	15	2 galv.	S	13.45	3/24/87	1.8	No	--	S&C	
81	19	3454040765435.1	DWS	25.4	CH	309	282	8	S	6.0S(?) 2.2P	4/66 3/24/87	2.5	Yes	G,L	F&L;USMC; USGS	
82	11; 53	3454160765421.1	DWS	24.4	CH	219	215	8	OH	10.8S 1.3S	Fall 1941 3/24/87	2.9	Yes	G,L	F&L;USMC; USGS	
83	12	3454060765424.1	DWS	23.6	CH	268	256	6	OH	12.2S 3.0S	Fall 1941 4/66	1.4	Yes	G,L	F&L;USMC; USGS	
84	30	3454130765358.1	--	19.7	PR	81	79	4	OH	12.32	12/47	0.8	Yes	L	USMC	Destroyed(?)
85	6	3454020765359.1	--	18.7	PR	91	87	4	OH	11.55	12/47	0.4	Yes	L	USMC	Destroyed(?)
86	11	3453470765409.1	--	25.0	CH	228.0	214	6	OH	10.92	12/47	1.3	Yes	L	USMC	Destroyed(?)
87	13	3454030765336.1	--	25.8	CH	131	117	4	OH	10.86	12/47	1.8	Yes	L	USMC	Destroyed(?)
88	40	3454040765328.1	COOL	27.7	CH	140	91	4	OH	7.7	Fall 1981	1.0	No	L	USMC	
89	41	3454050765326.1	COOL	28	CH	134	113.5	4	OH	13.5	Fall 1981	0.5	No	L	USMC	
90	31	3454010765242.1	--	25.1	CH	160	127	6	OH	6.48P(?)	12/47	1.2	Yes	L	USMC	Destroyed(?)
91	7	3453460765252.1	--	23.9	CH	209.0	195	4	OH	10.12	12/47	5.5	Yes	L	USMC	Destroyed(?)
92	9	3453560765321.1	--	26.0	CH	128	110	4	OH	11.42	--	3.2	No	--	USMC	Well under runway apron, Destroyed(?)
93	10	3453530765336.1	--	25.9	CH	219	211	6	OH	11.35	12/47	2.3	Yes	L	USMC	Destroyed(?)
94	35	3453580765350.1	COOL	24.7	PR	105	68.5	8	OH	13.6	Fall 1941	0.5	No	L	USMC	
95	5	3453590765351.1	COO1	22.5	PR	81	81	4	OE	11.72	12/47	0.02	Yes	L	USMC	
96	68	3453570765353.1	COOL	21.5	CH	203	150	8	OH	--	--	1.0	No	--	USMC	Replaced cooling Well 5
97	14; 54	3453570765421.1	DWS	23.4	CH	214	207	8	OH	11.7S 3.8S	Fall 1941 3/24/87	3.3	Yes	G,L	F&L;USMC; USGS	
98	18; 3	3453530765435.1	ABD	24.5	CH	215	211	6	OH	7.3S	4/66	1.6	No	--	F&L;USMC; USGS	Well destroyed
99	15; 62	3453470765420.1	DWS	18.1	CH	220	203	8	OH	14.5S -14.7P	5/21/42 3/24/87	3.2	Yes	G,L	F&L;USMC; USGS	
100	16	3453370765418.1	DWS	17.5	CH	232	226	8	OH	6.4S	4/66	1.8	Yes	G,L	F&L;USMC; USGS	
101	16GW01	3453250765421.1	M	23.3	WT	25	10	2 PVC	S	4.38	3/26/87	1.5	Yes	--	NUS	
102	16GW02	3453220765430.1	M	6.1	WT	25	10	2 PVC	S	1.53	3/26/87	1.4	Yes	--	NUS	
103	17	3453270765413.1	DWS	22.7	CH	250	231	8	OH	6.2S -1.6P	4/66 3/24/87	2.5	Yes	G,L	F&L;USMC; USGS	

Table 2.--Records of selected wells--Continued

Map well number (fig.4)	Coop-erator well number(s)	USGS identi-fication number	Use	Land surface altitude above sea level (feet)	Aquifer	Total well depth below land surface (feet)	Casing length (feet)	Diameter (inches) and casing material	Fin-ish	Water level above or below (-) sea level (feet)	Date of water-level measure-ment	Height of measuring point above or below (-) land surface (feet)	Water-quality analysis	Geophysical or litho-logical log	Data source	Remarks
104	NARF3	3453240765359.1	IWS	--	--	--	--	--	--	--	--	--	--	--	--	
105	NARF2	3453300765357.1	IWS	--	--	--	--	--	--	--	--	--	--	--	--	
106	26; NARF1;4	3453420765355.1	IWS	20(e)	CH	289	224	8	OH	11.7S(e) 2.3S(e)	Fall 1941 3/24/87	2.8	Yes	G,L	USMC;USGS	
107	15GW01	3435430765330.1	M	26.2	WT	25	10	2 PVC	S	15.77	3/27/87	1.3	Yes	--	NUS	
108	15GW02	3453400765333.1	M	25.0	WT	25	10	2 PVC	S	15.83	3/27/87	1.3	Yes	--	NUS	
109	15GW03	3453370765336.1	M	23.5	WT	25	10	2 PVC	S	15.46	3/27/87	1.4	Yes	--	NUS	
110	29	3452580765423.1	--	19.2	PR(?)	116	115	4	OH	16.43	12/47	1.5	Yes	L	USMC	Destroyed(?)
111	1	3453000765419.1	--	11.0	PR	97.0	98	8	OH	11.00	12/47	2.4	Yes	L	USMC	Destroyed(?)
112	2	3453030765413.1	--	16.0	CH	164.0	166	4	OE	13.07	12/47	1.6	Yes	L	USMC	Destroyed(?)
113	21GW01	3452530765138.1	M	20.1	WT	25	10	2 PVC	S	8.51	3/26/87	1.3	Yes	--	NUS	
114	21GW05	3452490765136.1	M	10.0	WT	25	10	2 PVC	S	7.23	3/26/87	1.4	Yes	--	NUS	
115	21GW04	3452440765134.1	M	14.0	WT	25	10	2 PVC	S	4.57	3/26/87	1.3	Yes	--	NUS	

Table 3.--Chemical analyses of water from wells in the Castle Hayne aquifer

[COOPERATOR WELL NUMBER: Number is that currently (1987) used by the Air Station personnel to identify water-supply wells. "D" after well number indicates duplicate sample. DWS: drinking water-supply well; IWS: industrial water-supply well; IRS: irrigation-supply well. DEG C: degrees Celsius. NTU: nephelometric turbidity units. US/CM: micro-siemens per centimeter. MG/L: milligrams per liter. UG/L: micrograms per liter. METHYLENE CHLORIDE, TOTAL (UG/L): "^" indicates change in detection limit dictated by laboratory atmosphere conditions. LINDANE, TOTAL: Total lindane (gamma benzene hexachloride (gamma BHC)). "<": detection limit for appropriate constituent, also constituent concentration below detection limit. NA: not analyzed. "*": indicates constituent exceeds ambient water quality criteria standard (EPA, 1986) or detection limit. "--": not applicable.]

MAP WELL NUMBER (fig. 4)	COOPERATOR WELL NUMBER	USE	SAMPLE COLLECTION DATE	SAMPLE COLLECTION TIME	FIELD TEMPERATURE (DEG C)	TURBIDITY (NTU)	COLOR (PLATINUM-COBALT UNITS)	FIELD SPECIFIC CONDUCTANCE (US/CM)	LAB SPECIFIC CONDUCTANCE (US/CM)	FIELD OXYGEN, DISSOLVED (MG/L)	FIELD PH (STANDARD UNITS)	LAB PH (STANDARD UNITS)
30	WELL 3	DWS	10-20-86	1103	18.0	20	40	442	452	1.3	7.27	7.40
29	WELL 4	DWS	10-17-86	1104	19.0	10	45	450	457	1.3	7.17	7.40
11	WELL 5	DWS	10-14-86	1100	21.5	32	35	400	439	1.1	7.50	7.40
19	WELL 6	DWS	10-15-86	1110	19.0	15	45	657	613	1.5	7.43	7.40
21	WELL 7	DWS	10-16-86	1107	18.5	67	12	447	442	1.0	7.21	7.80
33	WELL 8	DWS	10-31-86	1208	18.5	14	5	421	418	1.9	7.20	7.40
74	WELL 9	DWS	10-22-86	1109	19.0	16	36	560	544	1.5	7.41	7.50
82	WELL 11	DWS	10-23-86	1111	19.0	120	17	426	424	1.6	7.25	7.40
83	WELL 12	DWS	11-04-86	1212	19.0	3.8	45	432	421	3.3	7.33	7.40
79	WELL 13	DWS	10-24-86	1113	18.0	100	38	411	402	1.3	7.26	7.50
97	WELL 14	DWS	10-27-86	1114	19.0	300	40	435	432	1.3	7.12	7.30
99	WELL 15	DWS	10-28-86	1215	20.5	65	33	400	427	1.9	7.26	7.40
100	WELL 16	DWS	10-29-86	1216	19.0	7.5	30	438	427	2.4	7.34	7.40
103	WELL 17	DWS	10-30-86	1217	19.5	27	15	458	444	2.3	7.24	7.40
81	WELL 19	DWS	10-10-86	1135	21.0	160	55	430	433	0.8	6.68	7.60
9	WELL 21	DWS	10-07-86	1130	19.0	42	24	425	441	1.4	6.87	7.50
8	WELL 22	DWS	10-08-86	1145	19.0	70	60	420	441	1.2	7.11	7.40
10	WELL 23	DWS	10-09-86	1125	19.0	80	23	445	452	1.0	7.01	7.40
100	WELL 16D	DWS	10-28-86	1624	NA	NA	NA	NA	NA	NA	NA	NA
12	WELL 25	DWS	11-05-86	1225	18.5	7.6	25	462	451	1.9	7.27	7.40
106	WELL 26	IWS	11-06-86	1226	21.0	33	13	437	432	2.5	7.28	7.40
2	WELL 27	IRS	11-07-86	1227	19.0	11	48	437	432	2.9	7.18	7.40

Table 3.--Chemical analyses of water from wells in the Castle Hayne aquifer--Continued

MAP WELL NUMBER (fig. 4)	COOPERATOR WELL NUMBER	USE	CARBON DIOXIDE DIS-SOLVED (MG/L AS CO2)	ALKA-LINITY WH WAT TOTAL FIELD MG/L AS CACO3	ALKA-LINITY LAB (MG/L AS CACO3)	BICAR-BONATE WH WAT TOTAL FIELD MG/L AS HCO3	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	NITRO-GEN, AMMONIA DIS-SOLVED (MG/L AS N)	NITRO-GEN, NITRITE DIS-SOLVED (MG/L AS N)	NITRO-GEN,AM-MONIA + ORGANIC DIS. (MG/L AS N)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N)
30	WELL 3	DWS	28	272	230	330	320	328	0.564	0.002	1.3	<0.01
29	WELL 4	DWS	30	268	233	330	290	304	0.262	0.002	0.8	<0.01
11	WELL 5	DWS	18	294	224	360	320	340	0.371	0.005	0.8	0.017
19	WELL 6	DWS	19	268	267	330	390	473	0.296	0.004	1.2	0.04
21	WELL 7	DWS	30	251	227	310	300	352	0.424	0.005	1.0	<0.01
33	WELL 8	DWS	27	241	218	290	270	286	0.305	<0.001	1.3	0.014
74	WELL 9	DWS	24	312	271	380	380	374	0.552	<0.001	1.4	<0.01
82	WELL 11	DWS	24	275	218	340	280	282	0.531	0.003	0.6	<0.01
83	WELL 12	DWS	20	297	218	360	280	292	0.408	0.002	2.4	0.039
79	WELL 13	DWS	25	235	205	290	270	308	0.234	<0.001	1.1	<0.01
97	WELL 14	DWS	33	227	222	280	270	324	0.549	0.004	0.4	0.018
99	WELL 15	DWS	24	225	222	270	280	292	0.42	0.001	1.3	<0.01
100	WELL 16	DWS	20	240	223	290	280	293	0.392	0.001	0.7	<0.01
103	WELL 17	DWS	26	245	230	300	290	293	0.37	<0.001	1.7	<0.01
81	WELL 19	DWS	130	321	185	390	350	272	0.52	0.003	0.6	<0.01
9	WELL 21	DWS	62	236	218	290	290	340	0.44	0.002	0.7	<0.01
8	WELL 22	DWS	38	250	222	310	310	300	0.292	0.002	0.8	<0.01
10	WELL 23	DWS	48	256	227	310	310	280	0.292	0.004	1.4	0.012
100	WELL 16D	DWS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
12	WELL 25	DWS	NA	301	235	370	340	317	0.507	0.001	0.5	<0.01
106	WELL 26	IWS	30	299	221	370	320	284	0.33	0.003	0.6	0.033
2	WELL 27	IRS	29	308	225	380	280	283	0.40	0.003	0.4	0.014

Table 3.--Chemical analyses of water from wells in the Castle Hayne aquifer--Continued

MAP WELL NUMBER (fig. 4)	COOPERATOR WELL NUMBER	USE	NITROGEN, NITRATE DISSOLVED (MG/L AS N)	PHOSPHORUS, ORTHO, DISSOLVED (MG/L AS P)	CARBON, ORGANIC DISSOLVED (MG/L AS C)	CYANIDE TOTAL (MG/L AS CN)	HARDNESS (MG/L AS CACO3)	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)	SODIUM, DISSOLVED (MG/L AS NA)	POTASSIUM, DISSOLVED (MG/L AS K)	CHLORIDE, DISSOLVED (MG/L AS CL)
30	WELL 3	DWS	NA	0.009	7.9	<0.01	210	79	2.6	19	4.2	9.2
29	WELL 4	DWS	NA	0.006	7.7	<0.01	230	89	2.2	10	3.4	9.8
11	WELL 5	DWS	0.012	0.001	8.0	<0.01	210	82	2.3	10	3.1	7.9
19	WELL 6	DWS	0.036	0.006	7.5	<0.01	200	75	2.8	64	4.4	43
21	WELL 7	DWS	NA	0.005	7.5	<0.01	220	85	2.3	8.7	3.2	7.5
33	WELL 8	DWS	NA	0.005	6.5	<0.01	210	81	2.1	7.8	2.7	7.8
74	WELL 9	DWS	NA	0.018	7.0	<0.01	170	60	4.0	58	7.4	16
82	WELL 11	DWS	NA	0.012	7.4	<0.01	210	78	2.8	11	4.3	6.9
83	WELL 12	DWS	0.037	0.021	8.0	<0.01	200	77	3.0	12	4.9	7.4
79	WELL 13	DWS	NA	0.008	6.5	<0.01	200	76	1.8	6.7	2.0	8.0
97	WELL 14	DWS	0.014	0.009	7.4	<0.01	200	74	3.4	12	5.8	7.6
99	WELL 15	DWS	NA	0.002	6.8	<0.01	200	76	3.6	12	6.1	7.5
100	WELL 16	DWS	NA	0.014	7.6	<0.01	200	75	3.5	12	5.7	7.6
103	WELL 17	DWS	NA	0.009	5.2	<0.01	230	86	3.4	8.5	4.1	9.3
81	WELL 19	DWS	NA	0.007	8.2	<0.01	230	86	3.8	11	5.8	7.5
9	WELL 21	DWS	NA	0.007	7.2	<0.01	200	78	2.4	16	4.1	9.3
8	WELL 22	DWS	NA	0.005	8.0	<0.01	230	86	2.7	14	4.D	8.1
10	WELL 23	DWS	0.008	0.004	7.6	<0.01	210	80	2.6	20	4.5	9.7
100	WELL 16D	DWS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
12	WELL 25	DWS	NA	0.004	6.7	<0.01	200	76	2.8	23	4.6	10
106	WELL 26	IWS	0.03	0.006	5.2	<0.01	210	78	3.6	11	5.9	10
2	WELL 27	IRS	0.011	0.002	7.2	<0.01	210	80	2.3	9.4	3.7	7.5
	EPA water quality criteria where appropriate (EPA, 1986)		10	--	--	0.2 0.02 mg/kg/day (new standard)	--	--	--	--	--	250

Table 3.--Chemical analyses of water from wells in the Castle Hayne aquifer--Continued

MAP WELL NUMBER (fig. 4)	COOPERATOR WELL NUMBER	USE	SULFATE DIS-SOLVED (MG/L AS SO4)	FLUO-RIDE, DIS-SOLVED (MG/L AS F)	SILICA, DIS-SOLVED (MG/L AS SIO2)	ARSENIC TOTAL (UG/L AS AS)	BERYL-LIUM, TOTAL RECOV-ERABLE (UG/L AS BE)	BORON, DIS-SOLVED (UG/L AS B)	CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD)	CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR)	COPPER, DIS-SOLVED (UG/L AS CU)	COPPER, TOTAL RECOV-ERABLE (UG/L AS CU)
30	WELL 3	DWS	8.0	0.2	35	2	<10	40	<1	17	1	25
29	WELL 4	DWS	6.2	0.2	31	2	<10	20	<1	15	2	16
11	WELL 5	DWS	6.0	0.2	32	1	<10	20	<1	11	<1	12
19	WELL 6	DWS	5.8	0.4	34	<1	<10	120	<1	16	2	19
21	WELL 7	DWS	5.4	0.5	35	<1	<10	20	<1	<1	<1	7
33	WELL 8	DWS	3.6	0.2	33	<1	<10	20	1	<1	2	34
74	WELL 9	DWS	7.2	0.5	36	<1	<10	120	<1	20	2	7
82	WELL 11	DWS	6.1	0.2	34	<1	<10	30	<1	<1	2	120
83	WELL 12	DWS	7.2	0.2	34	2	<10	30	1	3	4	46
79	WELL 13	DWS	5.6	0.2	26	1	<10	30	2	5	2	43
97	WELL 14	DWS	4.8	0.2	33	<1	<10	30	<1	<1	<1	9
99	WELL 15	DWS	4.8	0.2	34	3	<10	30	<1	8	2	80
100	WELL 16	DWS	6.9	0.3	33	<1	<10	30	<1	<1	2	28
103	WELL 17	DWS	4.9	0.2	32	1	<10	30	<1	<1	2	80
81	WELL 19	DWS	6.3	0.3	32	14	10	30	<1	26	2	60
9	WELL 21	DWS	5.9	0.2	29	1	<10	40	<1	9	3	29
8	WELL 22	DWS	8.0	0.2	34	1	<10	30	<1	3	<1	19
10	WELL 23	DWS	6.2	0.2	33	<1	<10	30	<1	2	2	36
100	WELL 16D	DWS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
12	WELL 25	DWS	6.0	0.2	34	<1	<10	50	3	<1	2	31
106	WELL 26	IWS	3.8	0.2	32	<1	<10	30	<1	<1	5	29
2	WELL 27	IRS	6.7	0.2	32	<1	<10	20	<1	<1	<1	4
EPA water quality criteria where appropriate (EPA, 1986)			--	--	--	50	37 ng/L	--	10	50	170 mg/L	--

Table 3.--Chemical analyses of water from wells in the Castle Hayne aquifer--Continued

MAP WELL NUMBER (fig. 4)	COOPERATOR WELL NUMBER	USE	IRON, DIS-SOLVED (UG/L AS FE)	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)	NICKEL, TOTAL RECOV-ERABLE (UG/L AS NI)	SILVER, TOTAL RECOV-ERABLE (UG/L AS AG)	ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN)	ANTI-MONY, TOTAL (UG/L AS ZN)	SELE-NIUM, TOTAL (UG/L AS SE)	DI-CHLORO-BROMO-METHANE TOTAL (UG/L)	CARBON-TETRA-CHLO-RIDE TOTAL (UG/L)	1,2-DI-CHLORO-ETHANE TOTAL (UG/L)
30	WELL 3	DWS	1,300*	<5	60*	9	<1	210	<1	<1	<0.2	<0.2	<0.2
29	WELL 4	DWS	1,600*	10	74*	4	<1	180	<1	<1	<0.2	<0.2	<0.2
11	WELL 5	DWS	170	<5	72*	1	2	150	<1	<1	<0.2	<0.2	<0.2
19	WELL 6	DWS	58	<5	74*	2	<1	140	<1	<1	<0.2	<0.2	<0.2
21	WELL 7	DWS	800*	<5	170*	<1	<1	100	<1	<1	<0.2	<0.2	<0.2
33	WELL 8	DWS	990*	5	83*	<1	<1	30	<1	<1	<0.2	<0.2	<0.2
74	WELL 9	DWS	520*	<5	28	<1	4	110	<1	<1	<0.2	<0.2	<0.2
82	WELL 11	DWS	230	11	160*	5	<1	140	<1	<1	<0.2	<0.2	<0.2
83	WELL 12	DWS	780*	7	91*	4	1	60	<1	<1	<0.2	<0.2	<0.2
79	WELL 13	DWS	1,500*	55*	110*	13	1	240	<1	<1	<0.2	<0.2	<0.2
97	WELL 14	DWS	160	6	43	5	<1	20	<1	<1	<0.2	<0.2	<0.2
99	WELL 15	DWS	440*	10	97*	7	<1	220	<1	<1	<0.2	<0.2	<0.2
100	WELL 16	DWS	560*	25	61*	<1	<1	60	<1	<1	<0.2	<0.2	<0.2
103	WELL 17	DWS	870*	28	79*	<1	<1	100	<1	<1	0.3*	<0.2	<0.2
81	WELL 19	DWS	980*	14	260*	48*	<1	370	2	<1	<0.2	<0.2	<0.2
9	WELL 21	DWS	1,000*	14	120*	3	<1	30	<1	<1	<0.2	<0.2	<0.2
8	WELL 22	DWS	820*	17	57*	3	<1	20	<1	<1	<0.2	<0.2	<0.2
10	WELL 23	DWS	480*	<5	140*	1	<1	20	<1	<1	<0.2	<0.2	<0.2
100	WELL 16D	DWS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
12	WELL 25	DWS	1,300*	400*	63*	400*	<1	1,800	<1	<1	<0.2	<0.2	<0.2
106	WELL 26	IWS	250	<5	230*	4	1	30	<1	<1	<0.2	<0.2	<0.2
2	WELL 27	IRS	470*	<5	64*	<1	1	1,100	<1	<1	<0.2	<0.2	<0.2
	EPA water quality criteria where appropriate (EPA, 1986)		300	50	50	13.4	50	5000	146	10	0.19 total halomethane	--	--

Table 3.--Chemical analyses of water from wells in the Castle Hayne aquifer--Continued

MAP WELL NUMBER (fig. 4)	COOPERATOR WELL NUMBER	USE	BROMOFORM TOTAL (UG/L)	CHLORODIBROMOMETHANE TOTAL (UG/L)	CHLOROFORM TOTAL (UG/L)	TOLUENE TOTAL (UG/L)	BENZENE TOTAL (UG/L)	ACENAPHTHYLENE TOTAL (UG/L)	ACENAPHTHENE TOTAL (UG/L)	ANTHRACENE TOTAL (UG/L)	BENZO B FLUORANTHENE TOTAL (UG/L)	BENZO K FLUORANTHENE TOTAL (UG/L)
30	WELL 3	DWS	<0.2	<0.2	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<10.0	<10.0
29	WELL 4	DWS	<0.2	<0.2	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<10.0	<10.0
11	WELL 5	DWS	<0.2	<0.2	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<10.0	<10.0
19	WELL 6	DWS	<0.2	<0.2	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<10.0	<10.0
21	WELL 7	DWS	<0.2	<0.2	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<10.0	<10.0
33	WELL 8	DWS	<0.2	<0.2	<0.2	<0.2	0.4*	<5.0	<5.0	<5.0	<10.0	<10.0
74	WELL 9	DWS	<0.2	<0.2	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<10.0	<10.0
82	WELL 11	DWS	<0.2	<0.2	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<10.0	<10.0
83	WELL 12	DWS	<0.2	<0.2	<0.2	<0.2	0.9*	<5.0	<5.0	<5.0	<10.0	<10.0
79	WELL 13	DWS	<0.2	<0.2	<0.2	<0.2	0.9*	<5.0	<5.0	<5.0	<10.0	<10.0
97	WELL 14	DWS	<0.2	<0.2	<0.2	<0.2	0.3*	<5.0	<5.0	<5.0	<10.0	<10.0
99	WELL 15	DWS	<0.2	<0.2	<0.2	<0.2	1.9*	<5.0	<5.0	<5.0	<10.0	<10.0
100	WELL 16	DWS	<0.2	<0.2	<0.2	<0.2	1.4*	<5.0	<5.0	<5.0	<10.0	<10.0
103	WELL 17	DWS	<0.2	0.3*	0.6*	<0.2	1.7*	<5.0	<5.0	<5.0	<10.0	<10.0
81	WELL 19	DWS	<0.2	<0.2	<0.2	0.2*	0.9*	<5.0	<5.0	<5.0	<10.0	<10.0
9	WELL 21	DWS	<0.2	<0.2	<0.2	<0.2	0.2*	<5.0	<5.0	<5.0	<10.0	<10.0
8	WELL 22	DWS	<0.2	<0.2	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<10.0	<10.0
10	WELL 23	DWS	<0.2	<0.2	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<10.0	<10.0
100	WELL 16D	DWS	NA	NA	NA	NA	NA	<5.0	<5.0	<5.0	<10.0	<10.0
12	WELL 25	DWS	<0.2	<0.2	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<10.0	<10.0
106	WELL 26	IWS	<0.2	<0.2	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<10.0	<10.0
2	WELL 27	IRS	<0.2	<0.2	<0.2	<0.2	0.2*	<5.0	<5.0	<5.0	<10.0	<10.0
EPA water quality criteria where appropriate (EPA, 1986)			--	0.19 total halomethane	0.19	14.3 mg/L 0.3 mg/kg/day (new standard)	0.66	--	--	--	--	--

Table 3.--Chemical analyses of water from wells in the Castle Hayne aquifer--Continued

MAP WELL NUMBER (fig. 4)	COOPERATOR WELL NUMBER	USE	BENZO-A-PYRENE TOTAL (UG/L)	DELTA BENZENE HEXA-CHLOR-IDE TOTAL (UG/L)	BIS 2-CHLORO-ETHYL ETHER TOTAL (UG/L)	BIS (2-CHLORO-ETHOXY) METHANE TOTAL (UG/L)	BIS (2-CHLORO-ISO-PROPYL) ETHER TOTAL (UG/L)	BUTYL BENZYL PHTHAL-ATE TOTAL (UG/L)	CHLORO-BENZENE TOTAL (UG/L)	CHLORO-ETHANE TOTAL (UG/L)	CHRY-SENE TOTAL (UG/L)	DIETHYL PHTHAL-ATE TOTAL (UG/L)
30	WELL 3	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
29	WELL 4	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
11	WELL 5	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
19	WELL 6	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
21	WELL 7	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
33	WELL 8	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
74	WELL 9	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
82	WELL 11	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
83	WELL 12	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
79	WELL 13	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
97	WELL 14	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
99	WELL 15	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
100	WELL 16	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
103	WELL 17	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
81	WELL 19	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
9	WELL 21	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
8	WELL 22	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
10	WELL 23	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
100	WELL 16D	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	NA	NA	<10.0	<5.0
12	WELL 25	DWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
106	WELL 26	IWS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0
2	WELL 27	IRS	<10.0	<0.01	<5.0	<5.0	<5.0	<5.0	<0.2	<0.2	<10.0	<5.0

Table 3.--Chemical analyses of water from wells in the Castle Hayne aquifer--Continued

MAP WELL NUMBER (fig. 4)	COOPERATOR WELL NUMBER	USE	DI-METHYL PHTHAL-ATE TOTAL (UG/L)	1,2-DI-PHENYL-HYDRA-ZINE TOTAL (UG/L)	ENDO-SULFAN SULFATE TOTAL (UG/L)	ENDO-SULFAN BETA TOTAL (UG.L)	ENDO-SULFAN ALPHA TOTAL (UG/L)	ENDRIN ALDE-HYDE TOTAL (UG/L)	ETHYL-BENZENE TOTAL (UG/L)	FLUOR-ANTHENE TOTAL (UG/L)	FLUOR-ENE TOTAL (UG/L)	HEXA-CHLORO-CYCLO-PENT-ADIENE TOTAL (UG/L)
30	WELL 3	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
29	WELL 4	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
11	WELL 5	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
19	WELL 6	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
21	WELL 7	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
33	WELL 8	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
74	WELL 9	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
82	WELL 11	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
83	WELL 12	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
79	WELL 13	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
97	WELL 14	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
99	WELL 15	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
100	WELL 16	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
103	WELL 17	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
81	WELL 19	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
9	WELL 21	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
8	WELL 22	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
10	WELL 23	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
100	WELL 16D	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	NA	<5.0	<5.0	<5.0
12	WELL 25	DWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
106	WELL 26	IWS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0
2	WELL 27	IRS	<5.0	<10.0	<0.01	<0.01	<0.01	<0.01	<0.2	<5.0	<5.0	<5.0

Table 3.--Chemical analyses of water from wells in the Castle Hayne aquifer--Continued

MAP WELL NUMBER (fig. 4)	COOPERATOR WELL NUMBER	USE	HEXA-CHLORO-ETHANE TOTAL (UG/L)	INDENO (1,2,3-CD) PYRENE TOTAL (UG/L)	ISO-PHORONE TOTAL (UG/L)	METHYL-BROMIDE TOTAL (UG/L)	METHYL CHLOR-IDE TOTAL (UG/L)	METHYL-ENE CHLO-RIDE TOTAL (UG/L)	N-NITRO-SODI-N-PROPYL-AMINE TOTAL (UG/L)	N-NITRO-SODI-PHENY-LAMINE TOTAL (UG/L)	N-NITRO-SODI-METHY-LAMINE TOTAL (UG/L)	NITRO-BENZENE TOTAL (UG/L)
30	WELL 3	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<5.0
29	WELL 4	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<5.0
11	WELL 5	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<5.0
19	WELL 6	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<5.0
21	WELL 7	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<5.0
33	WELL 8	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<5.0
74	WELL 9	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<5.0
82	WELL 11	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<5.0
83	WELL 12	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<5.0
79	WELL 13	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<5.0
97	WELL 14	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<5.0
99	WELL 15	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<5.0
100	WELL 16	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<5.0
103	WELL 17	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<5.0
81	WELL 19	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<5.0
9	WELL 21	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.5^	<5.0	<5.0	<5.0	<5.0
8	WELL 22	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.5^	<5.0	<5.0	<5.0	<5.0
10	WELL 23	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.5^	<5.0	<5.0	<5.0	<5.0
100	WELL 16D	DWS	<5.0	<10.0	<5.0	NA	NA	NA	<5.0	<5.0	<5.0	<5.0
12	WELL 25	DWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<5.0
106	WELL 26	IWS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<5.0
2	WELL 27	IRS	<5.0	<10.0	<5.0	<0.2	<0.2	<0.2	<5.0	<5.0	<5.0	<5.0

Table 3.--Chemical analyses of water from wells in the Castle Hayne aquifer--Continued

MAP WELL NUMBER (fig. 4)	COOPERATOR WELL NUMBER	USE	PARA-CHLORO-META CRESOL TOTAL (UG/L)	PHENAN-THRENE TOTAL (UG/L)	PYRENE TOTAL (UG/L)	TETRA-CHLORO-ETHYL-ENE TOTAL (UG/L)	TRI-CHLORO-FLUORO-METHANE TOTAL (UG/L)	1,1-DI-CHLORO-ETHANE TOTAL (UG/L)	1,1-DI-CHLORO-ETHYL-ENE TOTAL (UG/L)	1,1,1-TRI-CHLORO-ETHANE TOTAL (UG/L)	1,1,2-TRI-CHLORO-ETHANE TOTAL (UG/L)
30	WELL 3	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
29	WELL 4	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
11	WELL 5	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
19	WELL 6	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
21	WELL 7	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
33	WELL 8	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
74	WELL 9	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
82	WELL 11	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
83	WELL 12	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
79	WELL 13	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
97	WELL 14	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
99	WELL 15	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
100	WELL 16	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
103	WELL 17	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
81	WELL 19	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
9	WELL 21	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
8	WELL 22	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
10	WELL 23	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
100	WELL 16D	DWS	<30.0	<5.0	<5.0	NA	NA	NA	NA	NA	NA
12	WELL 25	DWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
106	WELL 26	IWS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
2	WELL 27	IRS	<30.0	<5.0	<5.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Table 3.--Chemical analyses of water from wells in the Castle Hayne aquifer--Continued

MAP WELL NUMBER (fig. 4)	COOPERATOR WELL NUMBER	USE	1,1,2,2 TETRA-CHLORO-ETHANE TOTAL (UG/L)	BENZOGHI PERYLENE TOTAL (UG/L)	BENZO A ANTHRACENE TOTAL (UG/L)	1,2-DI-CHLORO-BENZENE TOTAL (UG/L)	1,2-DI-CHLORO-PROPANE TOTAL (UG/L)	CHLORO-ETHYL-ENE TOTAL (UG/L)	1,2,4-TRI-CHLORO-BENZENE TOTAL (UG/L)	DIBENZO AHANTHRACENE TOTAL (UG/L)	1,3-DI-CHLORO-PROPANE TOTAL (UG/L)
30	WELL 3	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
29	WELL 4	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
11	WELL 5	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
19	WELL 6	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
21	WELL 7	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
33	WELL 8	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
74	WELL 9	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
82	WELL 11	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
83	WELL 12	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
79	WELL 13	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
97	WELL 14	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
99	WELL 15	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
100	WELL 16	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
103	WELL 17	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
81	WELL 19	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
9	WELL 21	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
8	WELL 22	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
10	WELL 23	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
100	WELL 16D	DWS	NA	<10.0	<5.0	<5.0	NA	NA	<5.0	<10.0	NA
12	WELL 25	DWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
106	WELL 26	IWS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2
2	WELL 27	IRS	<0.2	<10.0	<5.0	<5.0	<0.2	<0.2	<5.0	<10.0	<0.2

Table 3.--Chemical analyses of water from wells in the Castle Hayne aquifer--Continued

MAP WELL NUMBER (fig. 4)	COOPERATOR WELL NUMBER	USE	1,3-DI-CHLORO-BENZENE TOTAL (UG/L)	1,4-DI-CHLORO-BENZENE TOTAL (UG/L)	2-CHLORO-ETHYL-VINYL-ETHER TOTAL (UG/L)	2-CHLORO-NAPH-THALENE TOTAL (UG/L)	2-CHLORO-PHENOL TOTAL (UG/L)	2-NITRO-PHENOL TOTAL (UG/L)	DI-N-OCTYL PHTHAL-ATE TOTAL (UG/L)	2,4-DI-CHLORO-PHENOL TOTAL (UG/L)	2,4-DI-NITRO-TOLUENE TOTAL (UG/L)
30	WELL 3	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
29	WELL 4	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
11	WELL 5	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
19	WELL 6	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
21	WELL 7	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
33	WELL 8	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
74	WELL 9	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
82	WELL 11	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
83	WELL 12	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
79	WELL 13	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
97	WELL 14	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
99	WELL 15	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
100	WELL 16	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
103	WELL 17	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
81	WELL 19	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
9	WELL 21	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
8	WELL 22	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
10	WELL 23	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
100	WELL 16D	DWS	<5.0	<5.0	NA	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
12	WELL 25	DWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
106	WELL 26	IWS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	<10.0	<5.0	<5.0
2	WELL 27	IRS	<5.0	<5.0	<0.2	<5.0	<5.0	<5.0	38.0*	<5.0	<5.0
EPA water quality criteria where appropriate (EPA, 1986)			--	--	--	--	--	--	15 mg/L phthalate esters	--	--

Table 3.--Chemical analyses of water from wells in the Castle Hayne aquifer--Continued

MAP WELL NUMBER (fig. 4)	COOPERATOR WELL NUMBER	USE	2.4,-DI-NITRO-PHENOL TOTAL (UG/L)	2,4,6-TRI-CHLORO-PHENOL TOTAL (UG/L)	2,6-DI-NITRO-TOLUENE TOTAL (UG/L)	3.3'-DI-CHLORO-BENZI-DINE TOTAL (UG/L)	4-BROMO-PHENYL PHENYL ETHER TOTAL (UG/L)	4-CHLORO-PHENYL PHENYL ETHER TOTAL (UG/L)	4-NITRO-PHENOL TOTAL (UG/L)	4,6-DINITRO-ORTHO-CRESOL TOTAL (UG/L)	DI-CHLORO-DI-FLUORO-METHANE TOTAL (UG/L)
30	WELL 3	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
29	WELL 4	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
11	WELL 5	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
19	WELL 6	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
21	WELL 7	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
33	WELL 8	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
74	WELL 9	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
82	WELL 11	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
83	WELL 12	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
79	WELL 13	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
97	WELL 14	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
99	WELL 15	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
100	WELL 16	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
103	WELL 17	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
81	WELL 19	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
9	WELL 21	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
8	WELL 22	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
10	WELL 23	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
100	WELL 16D	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	NA
12	WELL 25	DWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
106	WELL 26	IWS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2
2	WELL 27	IRS	<20.0	<20.0	<5.0	<25.0	<5.0	<5.0	<30.0	<30.0	<0.2

Table 3.--Chemical analyses of water from wells in the Castle Hayne aquifer--Continued

MAP WELL NUMBER (fig. 4)	COOPERATOR WELL NUMBER	USE	AROCLOR 1016 PCB TOTAL (UG/L)	PHENOL (C6H-5OH) TOTAL (UG/L)	NAPHTH-ALENE TOTAL (UG/L)	TRANS-1,3-DI-CHLORO-PROPENE TOTAL (UG/L)	CIS 1,3-DI-CHLORO-PROPENE TOTAL (UG/L)	METHY-LENE BLUE ACTIVE SUB-STANCE (MG/L)	PENTA-CHLORO-PHENOL TOTAL (UG/L)	1,2-DIBROMO ETH-YLENE TOTAL (UG/L)	BIS(2-ETHYL HEXYL) PHTHAL-ATE TOTAL (UG/L)
30	WELL 3	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.03	<30.0	<0.2	<5.0
29	WELL 4	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.08	<30.0	<0.2	<5.0
11	WELL 5	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.05	<30.0	<0.2	<5.0
19	WELL 6	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.05	<30.0	<0.2	<5.0
21	WELL 7	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.06	<30.0	<0.2	<5.0
33	WELL 8	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.04	<30.0	<0.2	<5.0
74	WELL 9	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.03	<30.0	<0.2	<5.0
82	WELL 11	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.03	<30.0	<0.2	<5.0
83	WELL 12	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.03	<30.0	<0.2	<5.0
79	WELL 13	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.02	<30.0	<0.2	<5.0
97	WELL 14	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.02	<30.0	<0.2	<5.0
99	WELL 15	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.02	<30.0	<0.2	<5.0
100	WELL 16	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.02	<30.0	<0.2	<5.0
103	WELL 17	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.02	<30.0	<0.2	<5.0
81	WELL 19	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.05	<30.0	<0.2	<5.0
9	WELL 21	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.06	<30.0	<0.2	<5.0
8	WELL 22	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.04	<30.0	<0.2	<5.0
10	WELL 23	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.04	<30.0	<0.2	<5.0
100	WELL 16D	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	NA	<30.0	<0.2	<5.0
12	WELL 25	DWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.04	<30.0	<0.2	<5.0
106	WELL 26	IWS	<0.1	<5.0	<5.0	<0.2	<0.2	0.04	<30.0	<0.2	<5.0
2	WELL 27	IRS	<0.1	<5.0	<5.0	<0.2	<0.2	0.04	<30.0	<0.2	<5.0

Table 3.--Chemical analyses of water from wells in the Castle Hayne aquifer--Continued

MAP WELL NUMBER (fig. 4)	COOPERATOR WELL NUMBER	USE	DI-N-BUTYL PHTHAL-ATE TOTAL (UG/L)	BENZI-DINE TOTAL (UG/L)	VINYL CHLO-RIDE TOTAL (UG/L)	TRI-CHLORO-ETHYL-ENE TOTAL (UG/L)	NAPH-THA-LENES, POLY-CHLOR. TOTAL (UG/L)	P,P' DDT, TOTAL (UG/L)	P,P' DDD, TOTAL (UG/L)	P,P' DDE, TOTAL (UG/L)	ALDRIN, TOTAL (UG/L)
30	WELL 3	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
29	WELL 4	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
11	WELL 5	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
19	WELL 6	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
21	WELL 7	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
33	WELL 8	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
74	WELL 9	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
82	WELL 11	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
83	WELL 12	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
79	WELL 13	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
97	WELL 14	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
99	WELL 15	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
100	WELL 16	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
103	WELL 17	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
81	WELL 19	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
9	WELL 21	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
8	WELL 22	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
10	WELL 23	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
100	WELL 16D	DWS	<5.0	<50.0	NA	NA	<1.0	<0.01	<0.01	<0.01	<0.01
12	WELL 25	DWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
106	WELL 26	IWS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01
2	WELL 27	IRS	<5.0	<50.0	<0.2	<0.2	<1.0	<0.01	<0.01	<0.01	<0.01

Table 3.--Chemical analyses of water from wells in the Castle Hayne aquifer--Continued

MAP WELL NUMBER (fig. 4)	COOPERATOR WELL NUMBER	USE	ALPHA BHC TOTAL (UG/L)	BETA BENZENE HEXA-CHLOR-IDE TOTAL (UG/L)	LINDANE TOTAL (UG/L)	CHLOR-DANE, TOTAL (UG/L)	DI-ELDRIN TOTAL (UG/L)	ENDO-SULFAN, TOTAL (UG/L)	ENDRIN, TOTAL (UG/L)	ETHION, TOTAL (UG/L)	TOX-APHENE, TOTAL (UG/L)
30	WELL 3	DWS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
29	WELL 4	DWS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
11	WELL 5	DWS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
19	WELL 6	DWS	<0.01	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
21	WELL 7	DWS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
33	WELL 8	DWS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
74	WELL 9	DWS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
82	WELL 11	DWS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
83	WELL 12	DWS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
79	WELL 13	DWS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
97	WELL 14	DWS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
99	WELL 15	DWS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
100	WELL 16	DWS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
103	WELL 17	DWS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
81	WELL 19	DWS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
9	WELL 21	DWS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
8	WELL 22	DWS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
10	WELL 23	DWS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
100	WELL 16D	DWS	<0.01	<0.01	<0.01	<0.1	<0.01	NA	<0.01	<0.01	<1
12	WELL 25	DWS	<0.01	<0.01	<0.01	<0.1	<0.01	NA	<0.01	<0.01	<1
106	WELL 26	IWS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1
2	WELL 27	IRS	<0.01	NA	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<1

Table 3.--Chemical analyses of water from wells in the Castle Hayne aquifer--Continued

MAP WELL NUMBER (fig. 4)	COOPERATOR WELL NUMBER	USE	HEPTA-CHLOR, TOTAL (UG/L)	HEPTA-CHLOR EPOXIDE TOTAL (UG/L)	AROCLOR 1221 PCB TOTAL (UG/L)	AROCLOR 1232 PCB TOTAL (UG/L)	AROCLOR 1242 PCB TOTAL (UG/L)	AROCLOR 1248 PCB TOTAL (UG/L)	AROCLOR 1254 PCB TOTAL (UG/L)	AROCLOR 1260 PCB TOTAL (UG/L)	MALA-THION, TOTAL (UG/L)
30	WELL 3	DWS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
29	WELL 4	DWS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
11	WELL 5	DWS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
19	WELL 6	DWS	<0.01	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
21	WELL 7	DWS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
33	WELL 8	DWS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
74	WELL 9	DWS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
82	WELL 11	DWS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
83	WELL 12	DWS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
79	WELL 13	DWS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
97	WELL 14	DWS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
99	WELL 15	DWS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
100	WELL 16	DWS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
103	WELL 17	DWS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
81	WELL 19	DWS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
9	WELL 21	DWS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
8	WELL 22	DWS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
10	WELL 23	DWS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
100	WELL 16D	DWS	<0.01	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
12	WELL 25	DWS	<0.01	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
106	WELL 26	IWS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
2	WELL 27	IRS	NA	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01

Table 3.--Chemical analyses of water from wells in the Castle Hayne aquifer--Continued

MAP WELL NUMBER (fig. 4)	COOPERATOR WELL NUMBER	USE	PARA-THION, TOTAL (UG/L)	DI-AZINON, TOTAL (UG/L)	METHYL PARA-THION, TOTAL (UG/L)	HEXA-CHLORO-BENZENE TOTAL (UG/L)	HEXA-CHLORO-BUT-ADIENE TOTAL (UG/L)	TOTAL TRI-THION (UG/L)	METHYL TRI-THION, TOTAL (UG/L)	MERCURY TOTAL RECOV-ERABLE (UG/L AS HG)	STYRENE TOTAL (UG/L)
30	WELL 3	DWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
29	WELL 4	DWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
11	WELL 5	DWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
19	WELL 6	DWS	0.02*	<0.01	0.06*	<5.0	<5.0	<0.01	0.18*	<0.1	<0.2
21	WELL 7	DWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
33	WELL 8	DWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
74	WELL 9	DWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
82	WELL 11	DWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
83	WELL 12	DWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
79	WELL 13	DWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
97	WELL 14	DWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
99	WELL 15	DWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
100	WELL 16	DWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
103	WELL 17	DWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
81	WELL 19	DWS	<0.01	<0.01	0.07*	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
9	WELL 21	DWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
8	WELL 22	DWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
10	WELL 23	DWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
100	WELL 16D	DWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	NA	<0.2
12	WELL 25	DWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
106	WELL 26	IWS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2
2	WELL 27	IRS	<0.01	<0.01	<0.01	<5.0	<5.0	<0.01	<0.01	<0.1	<0.2

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the
DEPARTMENT OF THE NAVY, U.S. MARINE CORPS

WATER RESOURCES INVESTIGATIONS 88-4034
PLATE 1

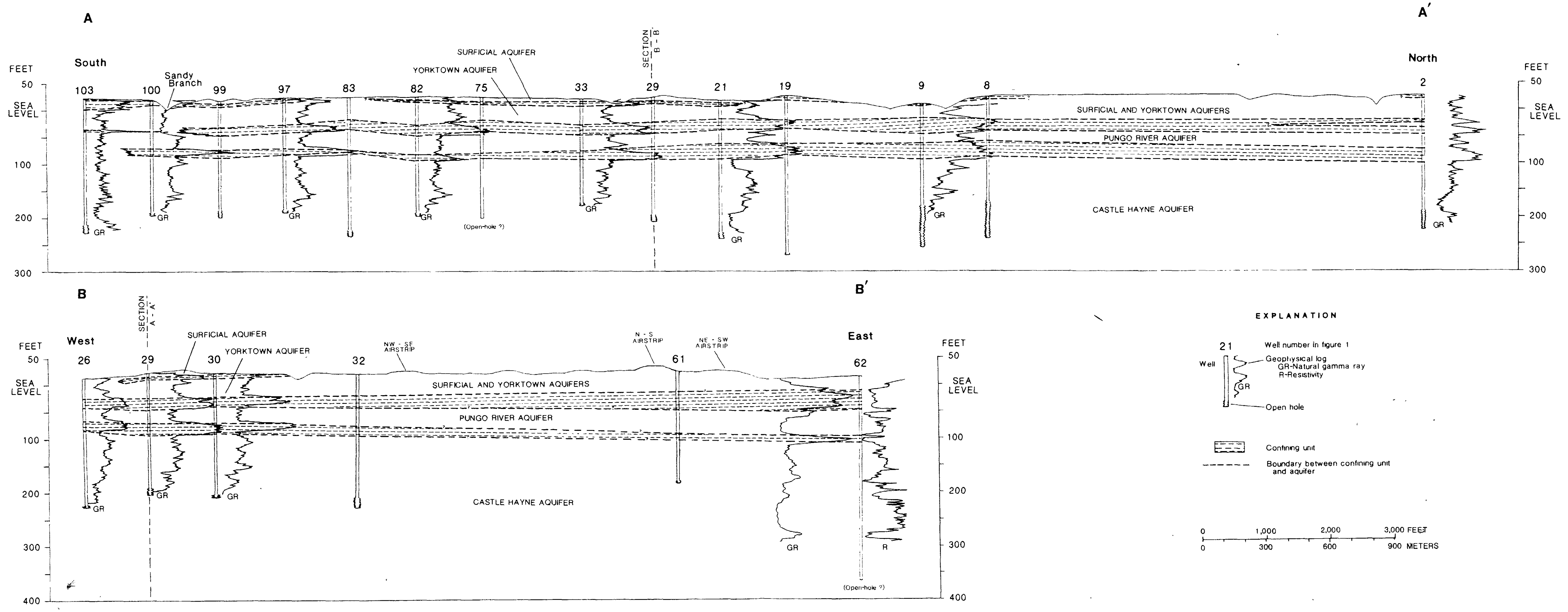

Plate 1. Hydrogeologic sections A-A′ and B-B′, U.S. Marine Corps Air Station, Cherry Point, North Carolina.